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## Animal Welfare

### *1 BISON INDUSTRY STAKEHOLDER PERCEPTIONS ON ANIMAL WELFARE, MANAGEMENT AND MEAT QUALITY*

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Objectives: The United States bison industry is growing both in size and popularity. As the industry grows, it is critical to identify current industry needs and challenges to ultimately drive improvement and profitability throughout the supply chain. Therefore, the objective of this study was to understand the perceptions of bison industry stakeholders regarding animal welfare, management, and meat quality.

Materials and Methods: A survey was developed in Qualtrics (XM, Seattle, WA). The primary targets for this survey were cow-calf producers, finishers, processors, distributors, and other individuals that work in the bison production and/or management business. Researchers attended the National Bison Association Winter Conference in Denver, Colorado, and offered individuals the opportunity to take the survey on an iPad (7th generation, Apple Inc., Cupertino, CA) or through their personal device via a QR code provided in a flyer given to all conference attendees. Respondents were not offered any incentive for participation. Seven days after the conference a reminder email was sent to all attendees. The survey had 22 questions including Likert, open ended, multiple answer, and demographic questions. Subjects included in the survey were animal welfare, production parameters, and meat quality. Demographic questions included age, gender, race, time working in the industry, size of operation, location of operation, and sector of the industry they work in. Descriptive statistics were performed using JMP (Statistical Discovery, NC) software.

Results: A total of 110 individuals answered the survey; however, they could skip questions if desired. Sixty percent ($n = 66$) of the respondents had been working in the bison industry for more than 10 y. In a question that allowed for multiple answers, many respondents indicated that their businesses were located in the Midwest and West regions of the United States (39.8%, $n = 45$, and 35.3%, 40 respectively). Twenty-one percent (23) of respondents agreed and 73.6% (81) strongly agreed that the bison industry should continue to expand and grow. Sixty-seven percent (74) of the individuals stated that the most important quality attribute of bison meat is flavor. In a question that allowed for multiple answers, respondents indicated that attributes that could benefit from improvements are marketing (64%, 70), animal health (45%, 51), and animal handling and welfare (38%, 42) from a provided list of focus areas. Approximately 96% (106) of the individuals agreed or strongly agreed that animal welfare is a critical component of the bison production system. In a Likert question, most respondents (99.3%, 109) indicated that animal welfare impacts meat quality. Approximately 60% (67) of the individuals agreed that transportation to the slaughter plant is an area of concern due to its potential impacts on animal welfare.

Conclusion: Survey respondents identified that animal welfare is a critical component of meat production. Further, respondents indicated that enhancements in bison transportation, product marketing, and overall animal health could be beneficial for the bison meat industry.

Funding Source: The funding was provided by the Bison Center of Excellence.

Keywords: animal welfare, bison industry, meat quality

# Consumer Topics

## 2 NUTRIGENOMICS OF BEEF: EVIDENCE OF ABSORPTION OF BEEF-DERIVED RNA SUGGESTS EPIGENETICS EFFECTS ON CONSUMER METABOLIC PATHWAYS

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Objectives: MicroRNAs (miRs) are noncoded RNAs that silence 60% of protein translation and alter metabolic pathways. In this study, we profiled the transcriptome of digested beef identifying the highest expressed miRs, investigated their intestinal absorption in mice, identified target genes that may be affected by absorbed miRs, and determined the miR profile of digested beef fed 2 distinct diets.

Materials and Methods: Trial 1: Strip loin steaks ($n = 4$) were aged for 14 d and cooked until the temperature reached 158°F. Two grams were digested with pepsin and trypsin and the remaining was blended in double deionized water to obtain a beef extract. Ten-week-old C57BL6/J mice ($n = 10$) were randomized into 2 groups and gavaged with a vehicle control (100 µL of deionized water, $n = 5$) or beef extract (100 µL, $n = 5$). After 3 h, mice were euthanized and the small intestine was collected. **Trial 2:** Strip loin steaks from carcasses fed grain (80%/20% corn/alfalfa hay, $n = 8$) and grass (100% alfalfa hay, $n = 8$) were aged for 14 d, cooked, and digested to estimate differences on miR profile. For both trials, total RNA from digested beef and mice small intestine was extracted and isolated via Triazol. Barcoded miRNA-Seq libraries were prepared using the NEXTflex Small RNA Sequencing v3 kit with randomized adapters. The libraries were quantified by fluorometry and sequenced with single-end 100 bp reads. MicroRNAs found in digested beef and mice intestines were validated via quantitative polymerase chain reaction. Effects on gene expression were predicted using TargetScan. Data were analyzed using the SPORTS computational pipelines. Counts per million (CPM) were used as the unit for expression. Differentially expressed miRNAs were identified by the edgeR tool.

Results: Trial 1: Overall, 413 bta-miRs were identified in digested beef. The 10 miRs with the highest logCPM counts were bta-miR-1-2 (26.97%), bta-miR-1-1 (26.97%), bta-miR-451 (8.66%), bta-miR-486 (6.97%), bta-miR-143 (1.78%), bta-miR-92a-1 (1.77%), bta-miR-133a-2 (1.69%), bta-miR-133a-1 (1.68%), bta-miR-92a-2 (1.54%), and bta-miR-22 (1.37%). The remaining miRs accounted for 20.60% of the total count. Out of the 10 highly expressed miRs, 4 were found in mice intestines, whereas the expression of miR-486 was significantly higher ($P = 0.008$) in mice fed beef. The miR-486 may target 174 genes based on its conserved transcription sites. **Trial 2:** The hierarchical clustering analysis showed that feeding cattle different diets affected the expression of 10 miRs in cooked beef. Those miRs modulate genes associated with tumorigenesis, diabetes, obesity, and growth development pathways.

Conclusion: Beef microRNAs are resistant to digestion and are absorbed in the small intestine. This study presents novel evidence that beef miRs may play an important nutrigenomic effect on human health due to their ability for modulating gene expression. Feeding cattle different diets alters the miR profile of beef, which may result in different metabolic responses after ingestion. This report presents groundbreaking data for the meat industry introducing beef RNA as a molecular nutrient. With the recent FDA regulatory clearance of gene-edited beef for human consumption and continuous advances in meat cultivation, future research seeking an optimal miR profile of meats will allow the industry to develop dietary recommendations and value-adding strategies from a molecular composition standpoint.

Keywords: beef, microRNA, nutrigenomics, nutrition

## 3 CONSUMER SENSORY EVALUATION OF THE IMPACT OF BONE-IN VS. BONELESS CUTS ON BEEF PALATABILITY

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Objectives: The objective of this study was to determine the palatability attributes of beef cuts of varying bone states and quality grades.

Materials and Methods: Both sides of 12 beef carcasses representing USDA Choice (upper 2/3) and USDA Select quality grades were selected by trained Kansas State University (KSU) personnel at a commercial abattoir in the Midwest. Cuts from both sides of carcasses were fabricated into beef short loins and bone-in and boneless ribeye rolls at the plant. Short loins were fabricated into either a boneless strip loin with a corresponding bone-in tenderloin or a bone-in strip loin with a boneless tenderloin at 3 d postmortem at the KSU Meat Laboratory. Product was aged for 28 d and then fabricated into 2.5-cm-thick steaks and frozen. Steaks were cooked to a peak temperature of 71°C on clamshell style grills. A total of 18 sensory panels were conducted at the KSU Meat Science Sensory Lab. Consumers evaluated samples for juiciness, tenderness, flavor liking, beef-like flavor intensity, beef fat–like flavor intensity, and overall liking on 100-point continuous line scales anchored on both ends with descriptive terms. Panelists were asked to classify each sample as acceptable or unacceptable for each of the sensory

traits previously listed. Data were analyzed as a split-plot design with a whole plot factor of quality grade and subplot factor of muscle/bone state.

Results: Overall, the effect of bone state on consumer eating experience was negligible. Bone state had no impact ($P > 0.05$) on consumer juiciness and overall liking for tenderloins and ribeyes, but in the strip loin, bone-in steaks were rated juicier ($P < 0.05$) and higher for overall liking ($P < 0.05$) when compared with boneless steaks. Bone state had no impact ($P > 0.05$) on consumer tenderness and flavor ratings for any of the 3 cuts. Tenderloin steaks were juicier, more tender, more flavorful, and rated higher overall ($P < 0.05$) than ribeyes and boneless strip loin steaks. There were no differences ($P > 0.05$) between strip loins and ribeyes for flavor liking. Ribeye steaks were similar ($P > 0.05$) to bone-in and boneless strip loin samples for tenderness and overall liking ratings. Bone state had no impact ($P > 0.05$) on the percentage of consumers rating juiciness as acceptable for tenderloins and ribeyes, but in strip loins, bone-in steaks had a higher ($P < 0.05$) percentage of acceptable consumer responses than boneless cuts. The percentage of acceptable consumer ratings for tenderness and overall acceptability was not ($P > 0.05$) impacted by bone state in tenderloins and strip loins; however, in ribeyes, the percentage of acceptable consumer ratings was higher ($P < 0.05$) for bone-in cuts for both traits. Tenderloins had a higher ($P < 0.05$) percentage of acceptable ratings for tenderness than strip loins and ribeyes. Tenderloins also had a higher ($P < 0.05$) percentage of acceptable ratings for juiciness and overall acceptability when compared with boneless strip loins and boneless ribeyes. Strip loin and ribeye steaks had similar ($P > 0.05$) percentages of acceptable juiciness ratings.

Conclusion: The results of this study indicate that a similar overall eating experience can be derived from a boneless steak as from a bone-in steak of the same cut and quality grade.

Keywords: beef, bone-in, boneless, consumer sensory analysis, tenderloin

## 4 CONSUMER PERCEPTION OF GROUND BEEF AND PLANT-BASED GROUND BEEF ALTERNATIVES IN A REAL-WORLD TACO SCENARIO

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Objectives: The objective of this study was to evaluate consumer acceptability and sensory traits of plant-based ground beef alternatives through evaluation in a "real-world" taco scenario.

Materials and Methods: This study included 4 treatments ($n = 20$ production lots/treatment), which included 80/20 ground beef, plant-based ground beef alternative (GBA), plant-based GBA typically sold in foodservice (FGBA), plant-based GBA typically sold at retail (RGBA), and "traditional" soy-based plant-based GBA (TGBA). Each product was selected due to its reputation as "well-known" in each market outlet. All products were purchased from 5 supermarkets in the Manhattan, Kansas, area over a 5-mo period. Product was stored frozen until consumer analysis. On each day of sensory panels, a separate production lot for each treatment was crumbled in a skillet and cooked to 165°F using an infrared thermometer. A commercially available taco seasoning was added to the crumbles while cooking following the manufacturer's instructions. Taco filling was served on soft flour tortillas, and consumers were allowed to apply toppings including cheese, lettuce, and diced tomatoes. Consumers ($n = 120$) evaluated samples for juiciness, tenderness, texture liking, flavor liking, beef-like flavor intensity, and overall liking on anchored continuous line scales. Each trait was identified as acceptable or unacceptable and classified at 1 of 4 quality levels—unsatisfactory, everyday quality, better than everyday quality, or premium quality. Consumers also rated their willingness to purchase each sample and identified a price they were willing to pay if purchased at foodservice.

Results: For most traits evaluated, ground beef (GB) was rated higher than the GBAs evaluated. GB was rated higher ($P < 0.05$) than all GBAs for all sensory characteristics evaluated, except for tenderness, in which GB was similar ($P > 0.05$) to both the FGBA and the RGBA. No difference ($P > 0.05$) was found between FGBA and RGBA for any of the sensory traits evaluated, with TGBA rating lower ($P < 0.05$) than all other treatments for each trait. However, a higher ($P < 0.05$) percentage of GB was rated acceptable than FGBA and RGBA for overall flavor liking, beef flavor liking, and overall liking. No difference ($P > 0.05$) was found among GB, FGBA, or RGBA in the percentage of samples rated acceptable for juiciness or tenderness. A greater ($P < 0.05$) percentage of FGBA was rated acceptable for both texture and beef flavor liking compared with RGBA, but no difference ($P > 0.05$) was found between the 2 for the percentage of samples rated acceptable for overall flavor and overall liking. Similar to the sensory ratings, a lower ($P < 0.05$) percentage of TGBA was rated acceptable for all traits compared with all other treatments, with the exception of texture liking, in which TGBA was similar ($P > 0.05$) to RGBA. Finally, GB had a higher ($P < 0.05$) purchase intent rating than 3 GBA.

Conclusion: When evaluated as a taco, GB provided an improved sensory experience and higher percentage of samples rated acceptable than most of the GBA treatments. Overall, consumers found the plant-based GBAs to be unacceptable. Therefore, GB and plant-based GBAs are not interchangeable when prepared in this manner and thus should be

considered as different products when marketing to consumers.

Funding Source: Funded by the Beef Checkoff.

Keywords: alternative protein, consumer, ground beef, sensory, taco

## 5 CONSUMER SENSORY EVALUATION OF GROUND BEEF AND PLANT-BASED GROUND BEEF ALTERNATIVES IN A "REAL-WORLD" EATING HAMBURGER SCENARIO

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Objectives: The objective of this study was to evaluate the palatability traits and consumer acceptance of 3 plant-based ground beef alternatives in comparison with ground beef in a foodservice-like pattied hamburger scenario.

Materials and Methods: One ground beef (80% lean; 0.45 kg chubs) and 3 commercially available plant-based ground beef alternative (GBA) treatments ($n = 20$ production lots/treatment) were purchased from 5 supermarkets in the Manhattan, Kansas, area over a 5-mo period. The plant-based GBAs were selected as representatives of GBAs well-known to be sold at foodservice (FGBA) and retail (RGBA). In addition, a popular "traditional" soy-based patty (TGBA) on the market was selected for use. Ground beef (GB) and the 3 GBA packages were stored frozen at the Kansas State University Meat Laboratory in Manhattan, Kansas, for no more than 4 mo, prior to patty fabrication. All lots were formed into 75 g patties to be served to consumers on a bun with opportunity to apply ketchup, mustard, cheese, lettuce, and pickles to samples. Patties were cooked to 71°C on a clamshell style grill (Cuisinart Griddler Deluxe, East Windsor, NJ). A total of 20 sensory panels were conducted at the KSU Meat Science Sensory Lab. Consumers ($n = 120$) evaluated samples for juiciness, tenderness, texture, flavor liking, beef-like flavor intensity, and overall liking on 100-point continuous line scales anchored on both ends with descriptive terms. Panelists rated each of the samples as acceptable or unacceptable for the sensory traits previously listed. Furthermore, panelists rated each sample on willingness to purchase on a 100-point continuous line scale and assigned a purchase price they would be willing to pay for each sample if purchasing a similar product at foodservice.

Results: Overall, GB was preferred by consumers compared with all 3 GBAs. GB rated higher ($P < 0.05$) for juiciness and texture compared with all GBAs. GB, FGBA, and RGBA tenderness ratings were similar ($P > 0.05$), but all 3 rated higher ($P < 0.05$) than the TGBA. Consumer ratings for overall flavor liking, beef-like flavor intensity, and overall liking showed GB was higher ($P < 0.05$) compared with all 3 GBAs. However, GB and FGBA were similar ($P > 0.05$) for the percentage of samples rated acceptable by consumers for juiciness and texture, but both had a higher ($P < 0.05$) percentage rated acceptable for these traits than RGBA and TGBA. Similar to the consumer ratings, the percentage of samples rated acceptable for tenderness for GB, FGBA, and RGBA were similar ($P > 0.05$), but all 3 had a higher ($P < 0.05$) percentage rated acceptable than the TGBA. GB had a higher ($P < 0.05$) percentage of samples rated acceptable for overall flavor liking, beef-like flavor intensity, and overall liking than all GBAs. Moreover, consumers rated GB higher ($P < 0.05$) for purchase intent than all GBAs and indicated they would be willing to pay a price more than 50% higher ($P < 0.05$) for the GB than all the GBAs.

Conclusion: When ground beef and plant-based ground beef alternatives are used as an ingredient, such as a hamburger patty, ground beef provided a different eating experience preferred by consumers. Therefore, the use of ground beef and ground beef alternatives provide different eating experiences when consumed as a complete hamburger and should be marketed as such by the foodservice and retail sectors.

Funding Source: Funded by the Beef Checkoff.

Keywords: beef, consumer, ground beef, ground beef alternatives, plant-based

# Meat and Poultry Quality

## 6 CONSUMER ACCEPTABILITY AND WILLINGNESS-TO-PAY OF WET-AGED BEEF STRIP STEAKS

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Objectives: Changes in beef flavor during aging may impact consumers' perception and their demand of beef products. This study examined the effects of wet aging on consumer acceptability and willingness-to-pay of beef strip steaks.

Materials and Methods: Twenty boneless beef loins (NAMP #180) of USDA Select were purchased from a commercial packing plant. Each loin was divided dorsally into 4 equal portions, randomized to receive either 0, 7, 14, or 21 d of aging, cut into two 2.5-cm-thick steaks (sensory) and one 1.3-cm-thick steak (chemical analysis). Steaks were vacuum packaged individually and aged in the dark. After aging, sensory steaks from all 20 loins were stored at −20°C until sensory analysis. Steaks were trimmed of external fat and connective tissues, wrapped in aluminum foil, cooked in a convection oven until the internal temperature reached 71°C, rested for 3 min, cut to six 1.3-cm × 1.3-cm × 2.5-cm cubes, and served to 130 consumers within 10 min of cooking and in sample cups with 3-digit codes. Consumers evaluated appearance, aroma, texture, flavor, and overall acceptability on a 9-point hedonic scale with 1 being dislike extremely and 9 being like extremely. A nonhypothetical auction method was used to obtain consumer willingness to pay (WTP). A Becker–DeGroot–Marshak auction was used as it is incentive-compatible. Allowable bids ranged from $0 to $28, centered on the current local market price for USDA Select beef steaks of $14/lb. Consumers bid on their steaks by $/lb while referring to their sensory results and were allowed to win only one randomly drawn steak after bidding. They were provided with a $21 voucher to fund their bid of a 12-oz (0.34 kg) steak. A cluster analysis was conducted using Ward's method within the Agglomerative Hierarchical Clustering procedure in XLSTAT software. Clustered sensory data were analyzed by the GLIMMIX procedure of SAS 9.4 with aging time as fixed effect and panelist as random effect. Independent product aggregate unit-demand curves were estimated using a fourth-degree polynomial to determine consumer demand as wet aging increased in the REG procedure of SAS 9.4. The degree of polynomial was chosen based on model fit and parameter significance. Actual probability values were reported.

Results: Consumers were separated into 6 clusters based on their overall acceptability. Cluster-1 ($N = 24$; $5.7 \pm 0.5$) consumers preferred flavor and texture of steaks aged for 0 and 21 d ($P \leq 0.014$). Cluster-2 ($N = 50$; $7.2 \pm 0.4$) preferred the texture of day-21 steaks ($P \leq 0.018$), whereas cluster-5 ($N = 10$; $3.4 \pm 0.7$) consumers preferred texture and flavor of day-7 and day-14 steaks ($P \leq 0.020$). Twenty-two consumers in cluster 4 and 6 preferred the aroma and texture of day-21 steaks ($P \leq 0.016$). However, 20 consumers in cluster 3 preferred the texture and aroma of day-0 and day-7 steaks ($P \leq 0.044$). Overall demand analysis indicated that 14-d steaks would be sold at 4.5, 4.5, and 6.1 units (lb) less ($P < 0.001$) than steaks aged for 0, 7, and 21 d if holding price constant at $14/lb. This represents a decrease in the WTP for 14-d steaks of $0.78/lb relative to day-0 and day-7 and $1.06/lb relative to day-21 steaks.

Conclusion: Wet aging drives the consumers' demand and WTP price by altering beef aroma, flavor, and texture. A decrease in consumer acceptance and demand for d-14 might be caused by less acceptable flavor and not-good-enough tenderness to overcome flavor degradation.

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

Keywords: beef, consumer acceptability, consumer demand, wet aging, willingness-to-pay

# Consumer Topics

## *7 MOUTH BEHAVIOR AND CONSUMER PREFERENCES OF GROUND BEEF PATTIES*

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Objectives: Food texture attributes have been used in sensory science for testing or predicting a product's acceptability by consumers. In meat products, ground beef texture has been related to consumer acceptance. However, consumers respond differently to texture attributes. The concept was developed that consumers can be classified into 4 texture categories (Crunchers, Chewers, Smooshers, or Suckers) based on mouth behavior. Our objective was to determine if consumers classified into 4 mouth behavior categories using the Jeltema Beckley Mouth Behavior (JBMB) graphic tool responded differently to ground beef differing in texture attributes.

Materials and Methods: Texture profile analysis was conducted where hardness 1, adhesion, hardness 2, cohesiveness, springiness, gumminess, and chewiness were calculated. Descriptive texture attributes of surface roughness, firmness, springiness, hardness, initial juiciness, mouthcoating, connective tissue amount, cohesiveness, cohesiveness of mass, particle size, particle amount, chewiness, toothpacking, and sustained juiciness were evaluated by a 5-member expert descriptive attribute panel. These measurements were used to understand ground beef texture differences using traditional meat science methods. Qualitative consumer evaluation was used to determine consumer attitudes toward ground beef patties differing in treatments. In Phase 1, four 227 g ground beef patty treatments (3 treatments of machine-formed patties containing 7%, 20%, or 27% chemical lipid and bowl chopped, machine-formed, 20% chemical lipid patties) and two 110 g patty treatments were bowl chopped and hand formed or formed into balls and smashed during cooking. One ground beef patty was served to each consumer across each mouth behavior category (Crunchers $n = 7$, Chewers $n = 5$, Smooshers $n = 5$, Suckers $n = 2$). In the Phase II, 7 foodservice (Wayback Burgers, Five Guys, Koppe Bridge, Whataburger, McDonald's, Sonic, and Freddy's) commercially prepared patties weighing approximately 110 g and 6 ground beef

products (round, sirloin and chuck packaged in chubs, brisket and chuck packaged in overwrap trays that were hand formed, and chuck patties machine formed at the retail location) were purchased from H-E-B.

Results: Patties were presented as in Phase I (Crunchers $n = 4$, Chewers $n = 7$, Smooshers $n = 3$, Suckers $n = 7$). Phase I ground beef patties differed ($P < 0.05$) in descriptive texture attributes of surface roughness, firmness, connective tissue amount, cohesiveness of mass, particle size, and chewiness; and textural profile analysis values of hardness 1, adhesion, gumminess, chewiness, and hardness 2. Phase II treatments differed ($P < 0.05$) in descriptive sensory attributes of surface roughness, firmness, springiness, hardness, mouthcoating, cohesiveness, particle size, chewiness, and sustained juiciness; and textural profile analysis values of hardness 1, hardness 2, cohesiveness, springiness, gumminess, and chewiness. Therefore, patties in both phases differed in texture. Consumers from Phase I perceived differences in fat level and processing method differently. Phase II consumer perceptions of foodservice ground beef patties differed from those of casual dining burgers across mouth behaviors. Round and brisket patties were differentiated from sirloin, and ground chuck patties were not rejected from any of the mouth behaviors.

Conclusion: Results indicate that mouth behavior classification impact consumer acceptance of ground beef patties based on difference in beef patty texture.

Keywords: consumer preference, descriptive panel, ground beef, mouth behavior, texture

# Education and Extension Tools

## *8 EVALUATION OF THE AMERICAN MEAT SCIENCE ASSOCIATION MEAT JUDGING PROGRAM SURVEY*

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Objectives: The objectives of this research were to evaluate the American Meat Science Association (AMSA) Intercollegiate Meat Judging program, how it affected participants, identify areas of strength and weakness in the program, and recommend changes to the program based on respondent feedback.

Materials and Methods: Intercollegiate meat judging participants ($n = 552$) voluntarily responded to a 10 to 15-min Qualtrics survey that was distributed via social media. The survey evaluated the AMSA meat judging program on areas of experiences of the meat judging program, skill building, introduction to the US meat industry, and areas of improvement for the meat judging program. Respondents were eligible to participate in the survey if they participated for a full year between the years of 1970 and 2019. Respondents were divided into 3 groups: A-Division participation ($n = 98$), Senior-Division participation ($n = 369$), and participation in both divisions ($n = 85$). Data were analyzed using the PROC FREQ procedure SAS Studio (SAS Institute, Cary, NC). This research was approved by the North Dakota State University Institutional Review Board; #0003573.

Results: Respondents were asked to rank 6 experiences: professional skills development, technical skills development, personal relationships, professional relationships, opportunity to travel, and exposure to the meat industry based on how important it was them personally and professionally. Across all groups, respondents reported professional skills development as the most beneficial experience. Additionally, respondents were asked to indicate their agreement on statements regarding whether the meat judging program helped them develop professional skills: interpersonal communication, organization, time management, decision-making, written communication, and development of a professional network. Across all groups, most respondents (> 80%) reported a positive agreement on statements. Furthermore, respondents were asked to rank 6 activities: meat science courses, meat judging, department clubs, internships/employment, AMSA activities, and other activities based on their influence on the respondent's understanding of the meat industry. Across all groups, meat judging was ranked highest on influencing respondent's understanding of the meat industry. Lastly, respondents were asked to provide insights on areas where the meat judging program could be improved. Responses were recorded from 102 respondents. Two major themes were noticed. The first theme ($n = 26$) was an emphasis on community building and development of professional networks, and the second theme ($n = 21$) was an emphasis on providing more industry applicability to meat judging contests.

Conclusion: The intercollegiate meat judging program was rated as a very positive and exceptionally beneficial experience. The program not only aids in development of important skills but also serves as an important gateway for many students into the meat and food industry. However, it would be beneficial to continue to explore new ways to connect participants with industry personnel. Another area of improvement identified included providing more industry applicability to the current meat judging contest structure. Lastly, AMSA has not defined the goals and mission of the intercollegiate meat judging program. Goals and a mission would provide more opportunity to showcase what the intercollegiate program accomplishes.

Keywords: education, meat judging, skills development, survey

## 9 OHIO'S COUNTY FAIRS BEEF CARCASS SHOWS (2018 TO 2021): SURVEY OF BEEF CARCASS CHARACTERISTICS RELATED TO QUALITY ATTRIBUTES

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Objectives: The state of Ohio consists of 88 counties that offer approximately 96 county fairs annually. A main attraction to these county fairs includes youth livestock exhibitions. Livestock exhibitions are organized to compare one animal against others to determine how they relate to the ideal conformation. These are a way of showcasing livestock that will soon enter the United States and Ohio food supply/meat industry. Numerous counties also host annual beef carcass shows for youth agricultural programs that include 4H and FFA participants. With an increase in carcass show entries and youth interest and participation, it would be beneficial to capture and understand how these carcasses compare on a national level (i.e., National Beef Quality Audit (NBQA)–2016). Therefore, the objectives include (1) investigating beef carcass characteristics of Ohio's county fair youth beef projects and (2) comparing beef carcass characteristics/quality attributes with national results.

Materials and Methods: Ohio counties with active beef carcass shows from 2018 to 2021 were selected to contribute beef carcass characteristic data. Beef carcasses ($n = 920$) were ribbed between the 12th and 13th ribs and allowed to bloom for 20 min. Carcasses were evaluated for yield grade (YG) and quality grade (QG) parameters. Tools used for evaluation included a USDA PYG Ruler (back fat thickness), ribeye dot grid (ribeye area), and USDA Marbling Cards (marbling scores). Statistical analysis included arithmetic means by MEANS SAS procedure, frequency distributions by PROC FREQ SAS procedure, and least-squares means and standard error of the mean by PROC GLIMMIX SAS procedure.

Results: Mean YG factors were backfat thickness, 1.2 cm; ribeye area, 88.8 $cm^2$; kidney, pelvis and heart fat, 2.0%, and hot carcass weight, 362.2 kg; resulting in a final YG of 2.7. Frequency distributions within YG included 20.2% YG 1, 44.9% YG 2, 29.5% YG 3, 4.7% YG 4, and 0.8% YG 5. Evaluating beef carcass characteristics between YG (1 to 5), backfat thickness increased ($P < 0.05$) and ribeye area decreased. Mean quality grade factors were skeletal maturity, $A^{40}$; lean maturity, $A^{72}$; and marbling score, $Small^{91}$; with an overall QG of $Select^{81}$. Frequency distributions within QG included 3.5% Prime, 75.5% Choice, 20.2% Select, 0.7% Standard, and 0.1% other (Commercial, Utility, Cutter, or Canner). When stratified by both YG and QG, the greatest distribution of carcasses was within YG 2, QG Choice (34.2%), followed by YG 3, QG Choice (24.9%). Lastly, comparing Ohio carcass show data to NBQA indicates carcasses were higher yielding (YG 2.7 vs. YG 3.1) with less backfat (1.2 cm vs. 1.4 cm) yet comparable in marbling score ($Small^{91}$ vs. $Small^{70}$) and QG ($Select^{81}$ vs. $Select^{96}$).

Conclusion: Youth livestock projects entering Ohio's county fair carcass shows demonstrate similarities to beef characteristics when compared with beef carcasses at the national level. As expected, beef cattle intended for youth livestock competitions yield carcasses that are higher yielding and slightly leaner, yet comparable in marbling score and quality grade. The current evaluation serves to exemplify the contribution of high-quality beef to the US meat industry, specifically Ohio's meat industry. This provides an opportunity for continuous educational programs regarding a better understanding of the impact of livestock management practices on meat quality.

Keywords: beef, beef grading, carcass shows, Ohio

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## 10 INTRODUCTORY BUTCHERING EXTENSION PROGRAMS FOR BEEF AND LAMB/GOATS INCREASE ATTENDEE SELF-REPORTED KNOWLEDGE AND CONFIDENCE IN MEAT SCIENCE TOPICS

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Objectives: In recent years, there has been increased interest from individuals to learn and experience meat animal harvest, fabrication, and processing. However, education in these areas is generally limited outside of university settings. This has created an opportunity to develop Extension activities to train Extension Educators, meat industry workers, meat animal producers, and consumers in the basic principles of meat science. Therefore, the objective of this program was to create an intensive, interactive Extension program to teach attendees in the areas of animal harvest, fabrication, processing, and food safety.

Materials and Methods: The pilot Extension program, Purdue University Boiler Butcher Basics, was developed for spring 2021. The in-person program had one 2-d workshop for beef ($n = 15$ attendees) and one for lamb/goats ($n = 10$ attendees). At the beginning of each workshop, electronic surveys (Qualtrics XM) were completed using tablets (Pre-Program). Attendees were asked categorical questions related to demographics (gender, ethnicity, race, and age). For each of the following parameters, attendees were asked to score their initial knowledge of and confidence to perform general animal harvest techniques, general carcass processing techniques, food safety techniques, and species-specific (pork or poultry) harvest and processing techniques. At the

end of the program, attendees were asked the same questions related to knowledge and confidence (Post-Program). All scores were determined using a 10-point slider scale that allowed for 1 decimal point with descriptions above the scale (0 = not knowledgeable/confident at all, 10 = extremely knowledgeable/confident). Each species program was analyzed separately, and attendees were given a random identifier to analyze differences in Pre-Program and Post-Program knowledge and confidence questions using a paired *t* test in SAS (SAS 9.4), with significance determined at $P < 0.05$ (IRB-2021-816).

Results: Attendees of the beef program had increased knowledge scores for general animal harvest techniques ($P = 0.0055$), fabrication ($P = 0.0045$), food safety ($P = 0.0065$), and beef-specific harvest and processing techniques ($P = 0.0059$) in addition to increased confidence to perform scores for harvest ($P = 0.0076$), fabrication ($P = 0.0074$), food safety techniques ($P = 0.0068$), and beef-specific harvest and processing techniques ($P = 0.0013$). Attendees of the lamb/goat program had increased knowledge scores for general animal harvest techniques ($P = 0.0003$), fabrication ($P = 0.0005$), food safety ($P = 0.0013$), and lamb/goat-specific harvest and processing techniques ($P < 0.0001$) in addition to increased confidence to perform scores for harvest ($P < 0.0001$), fabrication ($P = 0.0005$), food safety techniques ($P = 0.0002$), and lamb/goat-specific harvest and processing techniques ($P < 0.0001$).

Conclusion: The pilot program was designed to develop a curriculum, determine protocols, create resource materials, and gain feedback from participants in order to develop a permanent annual Boiler Butcher Basics program. Both beef and lamb/goat programs were impactful at increasing attendees' reported knowledge and confidence scores. However, long-term surveys need to be generated to determine the impact to workforce development in order to effectively conclude the impact of the program to industry needs.

Keywords: education, extension, fabrication, harvest, training

## 11 IMPLEMENTATION OF A GROUP QUIZ FORMAT IN AN INTRODUCTORY MEAT SCIENCE COURSE

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Objectives: Improving classroom engagement and performance is a constant aim for instructors, and concerns over decreased engagement and performance have been heightened during the COVID-19 pandemic. Student discussion as a method of indirect instruction can be effectively used to improve engagement in a classroom. Our objective was to improve engagement and grades in an introductory meat science course by incorporating a small amount of discussion time using a group quiz format. The hypothesis was that students would perform better on group quizzes than individual quizzes and their exam scores from units when group quizzes were used would be higher than exam scores when individual quizzes were used.

Materials and Methods: The study was conducted in the Animal Science 210: Animal Products course during the fall 2021 semester with 42 enrolled students. The course was split into 4 units containing 3 quizzes and 1 noncumulative exam. Each quiz was worth 10 points. Group quizzes were given in the first and third units, and individual quizzes were given in the second and fourth units. For group quizzes, students were given approximately 10 min to complete the quiz individually followed by 3 min of discussion in groups of 3 to 4 students where answers could be changed. Students were randomly assigned to groups. The same groups were used for all quizzes in unit one and new groups were assigned for quizzes in unit three. Students were not given time to discuss or change answers during individual quizzes. A paired *t* test was used to compare score averages between group quizzes and individual quizzes and to compare exams scores from units one and three to units two and four. Quizzes that were not attempted were given a score of 0 and were excluded from the analysis. An average of 7 students did not attempt quizzes for each quiz. A questionnaire containing Likert items was delivered to the students after the final quiz. The project was approved as exempt by the University of Nebraska-Lincoln Institutional Review Board under project number 20211121483EX.

Results: Student's average scores between group quizzes and individual quizzes were not different ($P = 0.79$). Group quizzes averaged 8.8 points and individual quizzes averaged 8.7 points. Average exam scores between group quiz units and individual quiz units also were not different ($P = 0.27$), with exams from group quiz units averaging 77.4% and exams from individual quiz units averaging 77.5%. Interestingly, results from the questionnaire indicated that the group quiz format was preferred by students. 72% of students responded "Strongly disagree" or "Disagree" when asked if they preferred all quizzes to be given individually, and 95% of students responded "Strongly agree" or "Agree" when asked if they valued discussing quiz problems with group members.

Conclusion: Although using the group quiz format did not improve grade performance, it was preferred by students in this class. Students believed the group quizzes to be beneficial to themselves and their group members.

Keywords: group quiz, student engagement, survey

## 12 PERCEPTIONS AND ATTITUDES OF YOUTH AND ADULTS REGARDING AFRICAN SWINE FEVER AND BIOSECURITY

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Objectives: African swine fever (ASF) is a high consequence foreign animal disease that is endemic to some Eastern European countries, the island of Sardinia, and most of sub-Saharan Africa. Although it has not yet been found in commercial swine populations in the United States, it has recently been observed in US territories and neighboring islands (Hispaniola). The US is the world's third largest producer of pork, and the potential introduction of ASF would severely disrupt hog and pork production, posing a tremendous risk to the domestic and global pork supply chain. Large swine producers, typically a division of a vertically integrated meat company, have strict biosecurity and visitor protocols in place to reduce the spread of disease. However, small or hobby swine producers, such as those who raise pigs for exhibition, may not have as stringent protocols. Additionally, the nature of youth swine shows promotes untracked movement of animals across the country. Further, individual exhibitions frequently take place during a relatively short period of time, facilitating viral incubation in the process. The role of the exhibition swine industry has been documented in the transmission of other swine viruses; however, their potential role in ASF transmission has not been evaluated.

Materials and Methods: In order to collect data on attitudes and perceptions of youth and adults in the exhibition swine industry toward ASF and biosecurity, anonymous digital surveys were distributed as approved in IRB protocols #3067 and #3075. Participants were asked to rate their knowledge and concern about ASF and biosecurity as well as provide information pertaining to the movement of swine for the purpose of exhibition.

Results: Data collection is ongoing, although preliminary results demonstrate a varied understanding of ASF and highlight potential opportunities to enhance biosecurity education to reduce the risk of transmission.

Conclusion: Results of this research will be utilized to inform the development of educational materials for adults and youth swine exhibitors. Additionally, results will be shared with livestock event planners and livestock associations to inform important behavioral modifications at livestock events, which may be necessary to maintain animal health and the global meat supply chain.

Keywords: African swine fever, biosecurity, education, pork production

# Environment, Production Systems

## 13 UTILIZING THE F94L MYOSTATIN GENE MUTATION TO IMPROVE CARCASS CHARACTERISTICS AND CUTOUT IN BEEF × DAIRY CROSSBRED CATTLE

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Objectives: Low muscularity in dairy cattle breeds results in poor carcass conformation, ill-shaped ribeyes, and poor carcass cutout yields. 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. The objective of this study was to determine the effect of the F94L myostatin mutation in beef × dairy mating systems on carcass traits and cutout yield.

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 1 copy of the F94L allele and 28 carcasses were from steers with 0 copies of the F94L allele. Carcass data were collected 48 h postmortem. One side of each carcass was fabricated first into beef subprimals to determine boxed beef yield and subsequently into retail cuts to determine retail yield. For boxed beef yield, the brisket was trimmed to 25-mm fat, 10 subprimals were trimmed to 6-mm fat, and 5 subprimals were trimmed to 0-mm fat. For retail yield, brisket flat and point were trimmed to 6-mm fat, strip steaks and ribeye steaks were trimmed to 3-mm fat, and all other retail cuts were trimmed to 0-mm fat. Lean trimmings for each carcass were analyzed for chemical fat content to adjust each carcass's trimmings to a standard 15% fat. The PROC MIXED procedure in SAS Studio (SAS Institute, Cary, NC) was used to analyze carcass and cutout 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 ribeye areas (98.6 versus 92.6 sq cm), greater ribeye width:length ratios (0.50 versus 0.48), lower USDA yield grades (2.38 versus 2.70), and lower marbling scores (416 versus 462) than carcasses from steers with zero F94L alleles ($P < 0.05$). For boxed beef yields, one F94L allele (versus zero F94L alleles) increased ($P < 0.05$) 85/15 trimmings (+1.89 kg), top round (+0.74 kg), strip loin (+0.35 kg), eye round (+0.27 kg), tenderloin (+0.18), boneless foreshank

(+0.18 kg), cap/wedge (+0.17 kg), tri-tip (+0.12 kg), pectoral meat (+0.08 kg), and back ribs (+0.07 kg). Overall, carcasses from steers with one F94L allele had greater boxed beef yields (49.7% versus 48.7%), boxed beef plus 85/15 trimmings yields (65.4% versus 63.8%), and total retail cuts plus 85/15 trimmings yield (64.1% versus 62.3%) than carcasses from steers with zero F94L alleles ($P < 0.05$).

Conclusion: The F94L myostatin mutation utilized in a beef × dairy breeding system resulted in lower marbling scores and increased muscularity as evidenced through larger, more symmetrical ribeyes, lower USDA yield grades, and higher carcass cutout yields (both boxed beef and retail yields).

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

Keywords: beef, cutability, dairy, myostatin, quality

## 14 ANTIBIOTIC RESISTANCE PATTERN OF BACTERIA ISOLATED FROM A SMALL-SCALE POULTRY FACILITY

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Objectives: Antimicrobial resistance (AMR) has emerged as a major public health problem. Antibiotic-resistant bacteria shedding in poultry feces may be transmitted to the environment as well as eggs. Therefore, the objective of this study was to determine the bacterial load and characterize the AMR patterns of bacterial isolates from a small-scale poultry facility.

Materials and Methods: A total of 50 environmental samples were collected at the Hopkins Avian facility of University of California during the summer of 2021. The facility has 2 houses: a layer house where adult layers were kept and a floor house where young chickens were kept after hatching. Three types of environmental samples were collected from the layer house: fecal samples ($n = 10$) from the floor, cage swabs ($n = 10$), and fresh egg swabs ($n = 10$). Two types of environmental samples were collected from the floor house: floor fecal samples ($n = 10$) and front door swabs ($n = 10$) of the pens. Samples were processed for isolation of generic *Escherichia coli* and *Salmonella* to calculate the prevalence of the 2 bacterial species. The populations of total aerobic bacteria were also determined. Additionally, 2 *E. coli* isolates from each positive sample were randomly selected for antimicrobial susceptibility to 23 antibiotics using the microbroth dilution method. One-way analysis of variance was used to compare the population of total aerobic bacteria and *E. coli* among the sample types. Fisher's exact test was used to compare the prevalence of *E. coli* and MIC data among sample types. The data were analyzed using R statistical software (4.1.2).

Results: No *Salmonella* isolates were recovered from any of the collected samples. Also, generic *E. coli* was not detected from layer house cage swab and egg swab samples. Generic *E. coli* counts were higher ($P < 0.05$) in the fecal samples collected from layer house (7.31 log CFU/g) and floor house (7.97 log CFU/g) compared with floor house door swab samples (3.04 log CFU/g). Similarly, aerobic bacteria counts were higher ($P < 0.05$) in fecal samples from both layer house (8.76 log CFU/g) and floor house (8.31 log CFU/g) compared with layer house cage swab (4.76 log CFU/g) and floor house swab (6.31 log CFU/g) samples, whereas egg samples had the lowest counts (4.10 log CFU/g). Twenty percent (12/60) of generic *E. coli* isolates were resistant to at least 1 drug, and 5% (3/60) of isolates were resistant to 3 or more microbial drugs. Generic *E. coli* isolates from the floor house door swab had higher ($P < 0.05$) prevalence of resistance (11/12, 91.60%) to the tested drugs compared with the floor house feces (1/12, 8.40%). High prevalence of resistance to ampicillin (8/12, 66.60%) and nitrofurantoin (3/12, 25.00%) was observed in *E. coli* isolates. All the isolates from the layer house feces were susceptible to the antibiotics tested.

Conclusion: Although the avian facility did not use any antibiotics on chicken, antimicrobial-resistant *E. coli* were still detected in certain environmental samples, indicating that the transmission of AMR is a complicated process. Additionally, the presence of antimicrobial-resistant *E. coli* in the front door swabs samples suggested that the facility may need to clean or sanitize the doors of the pen/chicken houses more frequently to minimize the spread of these bacteria to the environment and employees via direct contact to the doors.

Funding Source: Western Center for Agricultural Health and Safety.

Keywords: antimicrobial resistance, *Escherichia coli*, aerobic bacteria, poultry facility

## 15 EFFECT OF ENVIRONMENTAL ENRICHMENTS ON FRESH AND PROCESSED MEAT QUALITY OF TURKEYS

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Objectives: There has been an increase in consumer interest related to animal welfare that has driven production practices to include environmental enrichments across various species, including turkeys. Although environmental enrichments have been investigated to determine impacts on turkey health and welfare, there are limited data to determine

the impact of these enrichments on fresh or processed turkey meat quality.

Materials and Methods: One hundred and forty-four turkeys were randomly assigned to 6 enrichment treatments: control (Con), pecking block (PB), platform (P), platform + straw bale (PSB), straw bale (SB), and tunnel (T). Each treatment was replicated within a barn, and a total to 2 barns were utilized (24 pens total). At 19 wk of age, turkeys were weighed (live weight, kg), and 6 birds per pen were harvested over 2 d ($n = 144$). A subset of 96 turkeys were fabricated into wings, boneless thighs, legs, and boneless breasts, 24 h postmortem. From the breast and thigh, three 1.25 cm samples were taken for pH, proximate analysis, and drip loss. From the breast, three 2.54 cm slices were taken for instrumental color, with all remaining breast sample used for further processed boneless turkey breast. Breast portions were pumped with a commercial brine to 110% by weight. Brined breast was then vacuum sealed and vacuum tumbled (9 rpm for 90 min, stopping every 15 min for 10 min). Tumbled breasts were stuffed into cellulose casings, thermally processed (internal temperature 68.3°C), and smoked to produce boneless turkey logs. From each log, eight 1.25-cm slices were taken for packaged purge loss, expressed moisture, instrumental color, and texture analysis. All treatment levels were analyzed using PROC GLM procedure of SAS (9.4, SAS Institute, Cary, NC), with statistical significance level set at $P \leq 0.05$.

Results: For fresh turkey, treatment impacted live weight with SB turkeys weighing the least; PB and T turkeys weighing the most; and PSB, C, and P intermediate in weight ($P = 0.007$). Treatment did not impact the carcass yields (breasts $P = 0.386$; thighs $P = 0.985$; wings $P = 0.210$; and legs $P = 0.574$). Treatment did not impact breast $L^*$ ($P = 0.777$), $a^*$ ($P = 0.796$), or $b^*$ ($P = 0.366$) or thigh $L^*$ ($P = 0.936$) and $a^*$ ($P = 0.067$), but PSB thighs displayed the highest $b^*$ values and PB thighs displayed the lowest $b^*$ values ($P = 0.037$). Finally, treatment did not impact breast drip loss ($P = 0.766$), thigh drip loss ($P = 0.933$), breast pH ($P = 0.197$), or thigh pH ($P = 0.385$). For processed turkey quality, treatment had no effect on $a^*$ ($P = 0.498$) or $b^*$ ($P = 0.831$) but was significant to $L^*$ with SB, T, P, and PSB having higher values; C having lower color values; and PB having intermediate values ($P = 0.024$). Treatment impacted expressed moisture with PB, PSB, C, and T having greater expressed moisture loss; P having the least; and SB having intermediate expressed moisture loss ($P = 0.041$). Finally, for processed turkey quality, treatment did not impact processing yield ($P = 0.058$) or packaged purge loss ($P = 0.581$).

Conclusion: The results indicate some variations of fresh and processed turkey quality in relation to environmental enrichments, but the impact of specific enrichments is not universally consistent across fresh and processed turkey parameters. Further analysis of muscle samples may indicate specific biochemical or structural differences that may further clarify the differences observed.

Keywords: fresh meat quality, processed meat quality, turkey, welfare

## 16 REDUCTION OF PATHOGENS IN FECAL SAMPLES COLLECTED FROM BEEF CATTLE TREATED WITH TWO DIFFERENT COMMERCIALLY AVAILABLE DIRECT-FED MICROBIALS

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Objectives: The purpose of this study was to compare the prevalence and/or concentration of *Escherichia coli* O157: H7, *Salmonella*, *Clostridium perfringens*, and Enterobacteriaceae (EB) in the feces of beef cattle to evaluate whether the administration of Probicon would have greater or similar effect on pathogen reduction compared with Bovamine Defend.

Materials and Methods: This study took place at a beef cattle feedlot in the Pacific Northwestern region of the United States, with a total of 16 pens (8 pens/treatment). A total of 3,708 cattle (1,854 head/treatment) were on the same feeding program prior to and during treatment for 103 d but were supplemented with 2 different direct-fed microbials throughout the treatment period: (i) Bovamine Defend (*Lactobacillus acidophilus* NP51 and *Propionibacterium freudenreichii* NP24; BD): 50 mg/hd/d; target dose 9 logCFU/hd/d, and (ii) Probicon (*Lactobacillus salivarius* L28; PC): 50 mg/hd/d; target dose 7 logCFU/hd/d. Composite fecal samples were collected every 21 d from the floor surface of each pen (6 samples/pen), over a 4-mo period from September 2021 to December 2021. Fecal samples were immediately chilled and shipped overnight to a third-party commercial laboratory who blindly received the samples. A total of 480 fecal samples were collected, 240 from BD treatment and 240 from PC treatment. The presence of pathogens was determined using IMS protocol combined with molecular confirmation in a third-party, independent laboratory. Statistical comparisons were conducted using general estimating equations (GEE) approach using "gee" package in R 4.1.1 (R Core Team, 2021). In the model, each composite sample was the experimental unit, treatment type and date of sampling were included in the models as categorical variables, and measurements were assumed to be nested within different pens ($\alpha = 0.5$).

Results: When referring to overall prevalence of each pathogen, both treatments had very low *Salmonella* prevalence (BD: 2/240, PC: 3/240) throughout the study period. Although *E. coli* O157: H7 prevalence was higher in pens treated with PC (BD: 119/240, PC: 131/240) due to a higher

prevalence in the beginning and middle of the study (Day 42: BD: 28/48, PC: 36/48, $P < 0.05$), at the end of the study, lower prevalence of *E. coli* O157:H7 was observed in pens compared with BD (Day 103: BD: 31/48, PC: 19/48, $P < 0.05$), indicating that PC would be more effective in reducing *E. coli* O157: H7 prevalence over the course of the feeding period. The effect of the treatment was not significant on the concentration of *E. coli* O157: H7 because similar $\log_{10}$MPN values were observed. The effect of PC treatment on *C. perfringens* prevalence was statistically significant (odds ratio = 0.19, $P < 0.05$). However, the difference in *C. perfringens* concentration was not statistically significant. Lastly, EB concentrations between the 2 treatments were statistically significantly different ($\log_{10}$CFU difference = 0.84, $P < 0.001$), and throughout the study average loads were 7.16 $\log_{10}$CFU/g for PC and 8 $\log_{10}$CFU/g for BD.

Conclusion: Data indicate that using Probicon as a preharvest intervention strategy in a feedlot setting to decrease fecal shedding of *E. coli* O157: H7, *C. perfringens*, and Enterobacteriaceae would have a greater reduction compared with Bovamine Defend.

Keywords: *Clostridium perfringens*, *Escherichia coli* O157: H7, fecal, feedlots, Probicon

## 17 CATTLE PERFORMANCE AND HEALTH PARAMETERS OF BEEF FEEDLOT CATTLE FED TWO COMMERCIALLY AVAILABLE DIRECT-FED MICROBIALS

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Objectives: The purpose of this study was to assess the effect of 2 different direct-fed microbials (DFM) in feedlot performance and overall animal health parameters of cattle during finishing stages of production to evaluate if a novel DFM can provide better or similar metrics compared with existing products.

Materials and Methods: This study was conducted in a commercial feedlot located in the Pacific Northwest region from September 2021 to December 2021. Probicon, composed of *Lactobacillus salivarius* (L28), and Bovamine Defend, composed of a mix of *Lactobacillus acidophilus* (NP51) and *Propionibacterium freudenreichii* (NP24), were fed to cattle in the feedlot for 103 d of feeding period. A total of 3,708 heads of cattle were assessed, 1,854 heads per DFM were distributed in 8 pens. Cattle was fed 50 mg/hd/d and the target dose was 7 LogCFU/head/d for Probicon and 9 LogCFU/head/d for Bovamine Defend. Health data, such as initial, final weight, and respiratory conditions, were collected from the feedlot animal health management system; this program is part of the feedlot standard operating procedures, and in this database, feedlot operators keep track of individual health performance of cattle. Several growth and production parameters were evaluated to determine performance metrics, which included initial weight, final weight, days on feed, dry matter intake, average daily gain, dry matter conversion, hot carcass weight, mortality, and number of respiratory diseases.

Results: The effect of Probicon was similar to Bovamine Defend treatments in terms of performance metrics including initial weight, final weight, days on feed, dry matter intake, average daily gain, dry matter conversion, hot carcass weight, mortality, and respiratory disease as reflected in Table 1. Most of the differences were not significant according to the *t* test ($P > 0.05$), except the number of respiratory diseases. Overall, the data show that the Probicon treatment decreases the risk of respiratory diseases when compared with Bovamine Defend with a risk ratio of 0.70 (95% CI: 0.54, 0.89, $P < 0.05$).

Conclusion: Direct-fed microbial treatments used in the finishing diets of cattle can help improve overall health and performance directly or indirectly. Probicon and Bovamine Defend have resulted in similar production parameters related to performance and growth in cattle. Overall, by probiotic supplementation to the diet, there was less respiratory disease when Probicon was used compared with Bovamine Defend. Studying new alternatives that improve the health of cattle during finishing stages of production is important, considering that these treatments can improve the overall well-being of the animal.

Keywords: animal health, Bovamine Defend, cattle performance, Probicon, probiotics

**Table 1.** The Impact of Probicon® vs. Bovamine Defend® in a Commercial Feedlot

| | Bovamine Defend | | Probicon | |
|---|---|---|---|---|
| Parameter | mean | se | mean | se |
| Initial Weight, lbs. | 856.25 | 4.20 | 856.88 | 4.62 |
| Final Weight, lbs. | 1442.30 | 11.70 | 1449.35 | 13.47 |
| Dry Matter Intake, lbs. | 25.86 | 0.12 | 25.76 | 0.17 |
| Average Daily Gain, lbs. | 3.63 | 0.08 | 3.69 | 0.09 |
| Dry Matter Conversion | 7.15 | 0.17 | 7.02 | 0.18 |
| Hot Carcass Weight, lbs. | 912.98 | 7.41 | 917.44 | 8.53 |
| Days on Feed | 162 | | 161 | |
| Mortality | 13 | | 13 | |
| Respiratory diseases | 145 | | 101 | |
| Medicine cost, $/head | $103.51 | | $78.23 | |

# Meat and Poultry Processing, Ingredient Technology, and Packaging

## 18 WATER BINDERS IN BEEF PATTIES INCREASE YIELD AND EXTEND SHELF LIFE

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Objectives: Identifying nonallergenic natural water binders to increase beef patty juiciness and extend shelf life would be beneficial to the beef industry. The objective of this study was to determine the effect of integrating water binders into beef hamburger patties on cooking yield, shelf life, and pH.

Materials and Methods: Water binder treatments included potato extract, citrus fiber, dried refried beans, potato peel, or no binder (control). Each batch contained 4.5 kg ground beef chuck clod (USDA Choice; IMPS 114; 84 lean:16 fat) and 15% water, 1% salt, 0.2% onion granules, and 2% of the designated binder treatment. Ingredients were added as a percentage of the meat block, and the batches were mixed for 2.5 min at 29 rpm. Six batches of each treatment were made, and 2 patties (1.59 cm thick, 151.2 g) from each batch were analyzed for each parameter. Patties were assigned to cooked storage analysis or retail display analysis. Fluid yield and lipid oxidation were measured on cooked, frozen (210 d; −20°C), and reheated patties. Patties were cooked and reheated on a clamshell style electric grill to a target internal temperature of 71°C, and final internal temperatures were recorded. Raw patties were placed on Styrofoam trays, overwrapped, and displayed in a retail display case (4°C) for 4 d to evaluate fluid loss, daily discoloration, and day 0 and 4 lipid oxidation. Lipid oxidation was analyzed using thiobarbituric acid reactive substances. Raw patties were used to measure pH on day 0 of retail display. Data were analyzed using a mixed model analysis of variance using SAS 9.4. Water binder treatments, time (retail display or cooked storage), and their interaction were assumed as fixed effects. Time was considered a repeated measure modeled as a compound symmetric correlation structure. Cook yield data analysis used peak cook temperature as a covariate. Significance was determined at $P < 0.05$.

Results: Patties containing citrus fiber improved reheat yield ($P = 0.031$) and overall yield ($P < 0.001$). Citrus patties had the lowest pH ($P = 0.001$) at 5.45. On day 0 and day 4 of retail display, patties containing a water binder treatment had less lipid oxidation than the control patties ($P < 0.001$). Additionally, the cooked, frozen, and reheated patties had less lipid oxidation when containing a water binder treatment than the control patties ($P < 0.001$). However, patties containing potato peels consistently had the greatest discoloration each day of retail display ($P < 0.001$).

Conclusion: Citrus fiber improved water retention in reheated patties, and all water binders delayed lipid oxidation in raw, cooked, frozen, and reheated patties. Increasing patty juiciness and delaying lipid oxidation will improve consumers' eating experience of reheated, precooked patties in settings such as school or hospital cafeterias.

Funding Source: We gratefully acknowledge financial support from Basic American Foods and the Idaho Ag Experiment Station.

Keywords: beef patty, cook yield, shelf life, water binder

## 19 EFFECTS OF ADDING OF EGG POWDER FROM HENS IMMUNIZED AGAINST PHOSPHOLIPASE A2 ON GROUND BEEF SHELF LIFE

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Objectives: Lipid oxidation in beef may be enhanced by the hydrolysis of phospholipids by phospholipase α2 (PLA2) during postmortem storage and retail display. Anti-phospholipase α2 (aPLA2) is an antibody that may be able to prevent PLA2 activity. Past research has shown that aPLA2 can be mass-produced in eggs from hens immunized against PLA2, and the resulting egg can be spray- or freeze-dried in egg powder (EP) to preserve the antibody activity. Therefore, the present study investigated the effect of incorporating 3 different levels of dried EP containing aPLA2 for its potential to extend ground beef shelf life.

Materials and Methods: Vacuum-packaged USDA choice striploins from 10 different beef carcasses were obtained from a USDA facility at 2 d postmortem. The next day, each loin was ground, divided into 4 equal batches, hand mixed with 0%, 0.4%, 0.8%, or 1.6% dried EP containing aPLA2 (w/w), vacuum packaged, and stored at 2°C for 14 d. After the storage period, each batch of ground beef was formed into four 114 g patties using a mold. Aerobically packaged patties were randomly assigned to 1 of 3 display times (day 0, 4, and 7) and displayed under fluorescent lighting at 0°C to 4°C in coffin-style retail cases. Percent visual discoloration was determined using a trained panel ($N = 7$). Additionally, $L^*$, $a^*$, and $b^*$ were measured using a colorimeter each day of display on the day 7 patties. At the end of each sample's designated display period, patties were removed from the overwrapped packaging, repackaged in

vacuum packaging, and stored at −80°C until analysis. Enzymatic activity of EP containing aPLA2 was assessed using an enzyme-linked immunosorbent assay from a crude antibody extraction using acidified PBS. Lipid oxidation status was measured on samples from all 3 retail display periods. The fatty acid (FA) profile was only determined on the day 0 samples.

Results: Throughout the 7 d of retail display, $a^*$ and $b^*$ values decreased and visual discoloration increased ($P < 0.05$). However, the inclusion of EP had no effect on beef patty visual discoloration, $a^*$ or $b^*$ ($P > 0.05$). The $L^*$ value was not altered ($P > 0.05$) due to EP concentration or display day. Lipid oxidation increased ($P < 0.05$) for all treatments throughout the 7 d display periods. Beef patties containing 1.6% EP had higher ($P < 0.05$) lipid oxidation than the rest of the treatments. The addition of 1.6% EP to ground beef increased the relative percentage of C11-18:1 trans, C18:2, C18:3, C20:1, and C22:6 but decreased the relative percentage of C17:0 and C17:1 when compared with other treatments ($P < 0.05$).

Conclusion: Adding more than 0.8% of EP containing aPLA2 in ground beef altered the FA profile by increasing the content of some polyunsaturated FA, particularly 18:2, which may likely lead to the enhanced lipid oxidation in ground beef patties. Although EP containing aPLA2 has been routinely used in other animal agricultural industries as a supplement to improve productivity, it did not demonstrate any effect to extend beef shelf life when incorporated into ground beef.

Keywords: anti-phospholipase a2, discoloration, fatty acids, lipid oxidation

## 20 IDENTIFYING ALTERNATIVE BEEF CUTS SUITABLE FOR USE AS BEEF FINGER STEAKS

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Objectives: An American regional specialty, finger steaks are iconic to the state of Idaho. Finger steaks are traditionally made with meat from the loin, which has a higher value than other beef primals. Therefore, the primary objective of this study was to evaluate tenderness and sensory characteristics of finger steaks made from the loin and lower values cuts from the beef chuck, sirloin, and round.

Materials and Methods: Beef strip loins ($n = 12$; IMPS #180), beef top rounds ($n = 12$; IMPS #168), beef clod hearts ($n = 12$; IMPS #114E), and beef top sirloins ($n = 12$; IMPS #184B) from USDA Choice carcasses were aged for 21 d. At the end of the aging period, all subprimals were fabricated into strips (1.27 cm × 1.27 cm × 7.62 cm). Finger steaks were systematically assigned to a consumer taste panel or Warner-Bratzler shear force (WBSF). Before WBSF analysis and consumer taste panels, a batter was formulated within guidelines commonly applied to battered meat products, and batter pickup and product yield were assessed for all muscles in the cooking process. Pickup refers to the amount of coating material adhering to the product based on the final weight.

Prior to the respective sampling sessions, finger steaks were cooked in fresh cooking oil at 188°C, and fry time was determined at 2 ½ min in order to meet 71°C degrees of doneness. WBSF was used to evaluate objective mechanical tenderness for each muscle. Consumer sensory panelists ($N = 120$) assessed finger steaks from each muscle based on the following traits: appearance, flavor, tenderness, and overall product acceptability using a 10-point scale where 1 = dislike extremely and 10 = like extremely, respectively. Additionally, consumers were asked if they would be willing to purchase a sample at a restaurant with options of yes, no, and unsure. Data were analyzed using a generalized linear model in SAS.

Results: Variation was observed between the subprimals indicating that the top round had the highest batter pickup percentage compared with the clod heart, which had the lowest pickup percentage ($P < 0.001$). There was a significant difference ($P < 0.002$) in tenderness between muscles, with striploin and top sirloin being the most tender. All muscles were considered tender based on USDA thresholds. Consumer taste panels indicated a difference in acceptability ($P < 0.001$), tenderness ($P < 0.001$), juiciness ($P < 0.002$), and flavor ($P < 0.006$) between treatments. As predicted the strip loin outperformed the other muscles in tenderness, juiciness, and acceptability. In categories of tenderness and acceptability, the clod heart and top sirloin were second highest compared with the strip loin. Clod heart, top sirloin, and striploin were ranked as superior flavor over top round. There was a significant difference within consumers' responses for willingness to purchase ($P < 0.004$).

Conclusion: Based on WBSF values and the consumer sensory panel, meat from the chuck and round were determined to be acceptable alternatives to the current traditional strip loin commonly used for finger steak production. The additional processing and value addition of beef in a finger steak application provides an opportunity to increase consistency and value for the meat industry.

Funding Source: We gratefully acknowledge financial support from the Idaho Beef Council.

Keywords: battered application, beef, consumer acceptability, underutilized cuts

## 21 EFFECT OF FAT PERCENTAGE, STORAGE TEMPERATURE, AND TIME ON REDNESS OF GROUND BEEF PATTIES IN CARBON MONOXIDE MODIFIED ATMOSPHERIC PACKAGING

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Objectives: Meat color is the most important quality attribute consumers associate with meat freshness and wholesomeness. Any deviation from bright cherry-red color results in discarded or discounted products because of a lack of consumer acceptance and possible spoilage. One of the biggest limiting factors of shelf life for fresh meat is the loss of color stability throughout storage. Although previous studies reported the use of carbon monoxide (CO) improved color stability, there has been limited research reporting the effect of fat percentage, temperature, and/or storage time. Thus, the objective of this study was to investigate the effects of fat percentage (27%, 19%, 7%), storage temperature (4.4°C, 2.5°C, −1.0°C), and storage time (1, 3, 10 d) on color of ground beef in CO modified atmosphere (CO-MAP) packaging.

Materials and Methods: Nine 4.5 kg ground beef chubs with a lean-to-fat ratio (L/F) of 73:27, 81:19, and 93:7 ($n = 3$ per L/F) were collected from Creekstone Farms in Arkansas City, KS. Ground beef chubs were stored for 7 d, then each chub per fat percentage was finely ground. From each batch, 227 g patties ($n = 162$) were formed and packaged in modified atmospheric packaging consisting of 0.4% CO, 30% $CO_2$, and 69.6% $N_2$. After packaging, patties within each fat percentage were randomly assigned to 1 of 3 storage temperatures: −1.0°C, 2.5°C, or 4.4°C and 1 of 3 dark storage times: 1 d, 3 d, or 10 d. On each respective pull day, 2 patties from each fat percentage × storage temperature were measured for instrumental surface raw color and internal cooked color, microbial growth, and lipid oxidation. Data were analyzed as a split-split plot using PROC GLIMMIX procedure of SAS. Least square means were calculated and considered significant at $P < 0.05$, using ANOVA testing to indicate significance. Using the PDIFF option, means were separated and deemed significant at $P < 0.05$.

Results: A significant storage time × fat level × storage temperature interaction resulted for $a^*$ values (redness). On day 1, 27% fat level ground beef patties stored at 4.4°C and 2.5°C had greater ($P < 0.05$) redness than −1.0°C. Irrespective of fat and storage time, −1.0°C storage decreased redness of ground beef patties compared with 2.5°C and 4.4°C. On day 10 of storage at 4.4°C, 27% fat level had greater ($P < 0.05$) redness than 7% and 19% fat level. In general, at 2.5°C and 4.4°C, greater storage time increased redness of patties at all fat levels. At all storage temperatures on days 1 and 3, 7% fat patties had less ($P < 0.05$) microbial growth compared with 19% and 27% patties.

Conclusion: The current study indicates that lower storage temperature decreased redness of ground beef patties. Lower temperatures decrease oxygen consumption; hence, the conversion of oxymyoglobin to carboxymyoglobin may be limited. Therefore, processors should use favorable temperatures to promote carboxymyoglobin and redness of patties stored in CO-MAP mother bags while maintaining other quality and safety attributes.

## 22 IMPACT OF PACKAGING SYSTEM ON THE MICROBIAL ECOLOGY OF RAW GROUND TURKEY

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Objectives: This study aims to determine the impact of packaging system on the bacterial community composition and predominant specific spoilage organisms (SSOs) of ground turkey.

Materials and Methods: Three separate lots of boneless skinless turkey breast were ground for 3 separate replicates. Ground turkey samples were assigned to one of the following: 1:High-oxygen modified atmosphere (MA) trays (80% oxygen/20% carbon dioxide flush), 2:Reduced oxygen MA tray (80% nitrogen/20% carbon dioxide flush). 3:Trays covered with an oxygen-permeable film on Styrofoam trays and packaged in an MA "mother bag" containing 80% nitrogen and 20% carbon dioxide, 4:Plastic chub, 5:Vacuum packaging. Packages were stored at 3°C for a specified number of days (1, 7, 14, 18, 21, 25) to ensure all treatments spoiled.

At each sampling time, pH was measured by entering probe directly into product in duplicate. Approximately 100 g of meat was aseptically transferred to stomacher bags and homogenized for 2 min. This homogenate was used for 16S sequencing on the Illumina platform and microbial plate counts. Aerobic (APC), anaerobic (AnPC), psychrotrophic (PSY), and lactic acid bacteria (LAB) plate counts were obtained from homogenate. APC, AnPC, and LAB were incubated at 37°C and counted at 48 h. AnPC were held in anaerobic chamber with oxygen absorbent packs. Psychrotrophs were incubated at 4°C and counted at 10 d.

Microbial counts and pH were analyzed with independent covariance structure using the nlme package. Means were separated using the emmeans package. Obtained 16S V4 region sequence reads were processed in R with the DADA2 pipeline to prepare generate amplicon sequence

variants (ASVs). ASVs were binned and taxa were assigned based on the Silva V138 database. Additionally, Mothur (1.42) was used to calculate phylogenetic distances. Weighed Unifrac distances were calculated to observe differences in bacterial community composition. Nonparametric permutation-based MANOVA was conducted with these beta diversity indices (R Package, vegan). Significance for all analyses was set at $P < 0.05$.

Results: There was a significant effect ($P < 0.05$) of storage time on pH because it declined over time in all treatments. Storage time had a significant effect on all plate counts because they increased over time ($P < 0.05$). A treatment by storage time interaction was observed in AnPC because treatment 1 took longer to reach 7 log CFU/g as anaerobes competed with fastidious aerobic organisms ($P = 0.0061$), illustrating how packaging plays a role in selecting organisms with differential metabolic flexibility. There was a significant day by treatment interaction ($P = 0.03$) on community structure. At day 0, all treatments had a sizeable proportion of *Pseudomonas* spp. Although treatment 4 retained a high proportion of *Pseudomonas* spp., treatment 1 enhanced growth of aerobic *Brochothrix* spp. Treatments 2, 3, and 5 had higher proportions of fermentative lactic acid bacteria over time likely selected by anoxic pressures.

Conclusion: Packaging atmosphere composition modulated bacterial communities to include greater relative abundance of *Brochothrix* or lactic acid bacteria over time; however, *Pseudomonas* spp. were common regardless of treatment, illustrating the predominant influence of the initial processing environment and starting materials.

Funding Source: Funded in part by the University of Nebraska Foundation and University of Nebraska Agricultural Research Division.

Keywords: microbial communities, poultry, spoilage

## 23 EFFECTS OF NOVEL TUMBLING APPLICATION AND POSTMORTEM AGING ON CULL COW BEEF LOIN TENDERNESS

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Objectives: Cull cow beef has been traditionally viewed as lower quality and less valuable by consumers due to its inferior meat quality characteristics, particularly its toughness. Several processing methods have been used to improve meat quality attributes. However, given an increasing demand for clean-label and minimally processed fresh products, developing a natural postharvest improvement strategy is needed. Tumbling with brines has been widely practiced in the processed meat application. However, tumbling without a brine has not been considered as a means to improve beef tenderness. In our recent studies, we have found consistent results that tumbling alone can significantly improve tenderness of beef loins. Therefore, the objective of this study was to investigate the effect of fresh beef tumbling on meat quality, proteolysis, and sensory attributes of cull cow beef loins.

Materials and Methods: At 5 d postmortem, loin muscles (*longissimus lumborum*) from 12 Holstein carcasses (USDA Boner grade; > 30 mo) were obtained and divided into 3 sections for treatment allocations: no tumbling control (NT), tumbling (T), and tumbling with spiked liner (TS). The sections were individually vacuum packaged and tumbled for 90 min at 8.5 rpm. Each section was divided into 2 subsections for aging effect (no further aging or aging 2 wk at 1°C). Multiple steak cuts were made for meat quality and biochemical measurements, including Warner-Bratzler shear force (WBSF), pH, instrumental color, water-holding capacity (WHC), myofibril fragmentation index (MFI), and western blot analyses for desmin, troponin-T, and calpain-1 autolysis. A consumer sensory evaluation ($n = 72$) was performed. Experimental design was a balanced complete block design. All data were analyzed using PROC MIXED procedure of SAS, and least-squares means for all traits were separated ($P < 0.05$).

Results: The WBSF results did not reveal a significant change in tenderness for the tumbling treatment. However, there was a numerical downward trend observed from tumbled and nonaged samples to tumbled with aging samples. Western blot analysis showed no significant differences in amount of proteolysis that occurred between tumbling treatments ($P > 0.05$). Tumbling treatments (T and TS) had no adverse impacts on water-holding capacity, color, or pH ($P > 0.05$). A consumer panel found that tumbled loins with no additional aging were more tender and higher overall liking scores compared with NT counterparts. The sensory panel also determined that tumbled beef loins (T and TS) with no further aging had equivalent tenderness liking and overall liking scores compared with CON samples with 2 wk of additional aging ($P > 0.05$), indicating the immediate positive impacts of tumbling on tenderness improvements.

Conclusion: The results of this study confirm that fresh beef tumbling without brine inclusion can result in considerable improvements in tenderness of cull cow beef loins without further aging. Further trials with investigating effects of different tumbling conditions (e.g., tumbling speed, time, etc.) on meat quality attributes should be warranted to maximize the positive impact of fresh beef tumbling as a simple and natural value-adding practice.

Funding Source: Indiana Beef Council and Beef Checkoff.

Keywords: cull cow beef, fresh meat tumbling, meat quality, proteolysis, tenderness

## 24 EFFECT OF BEEF EPIMYSIUM (SILVER SKIN) LEVEL ON EMULSION STABILITY AND MEAT PRODUCT QUALITY

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Objectives: Silver skin (epimysium) is a collagen-rich fascia that recovers individual muscles. Silver skin is usually trimmed off the meat during processing because of possible negative effects on product quality. This study aimed to evaluate the effect of beef epimysium (silver skin) inclusion levels on meat emulsion stability and cooked meat product quality.

Materials and Methods: Pork loins were purchased from 3 local markets, trimmed for external fat, ground, and mixed with ground beef, fat trimmings, water, and spices. Three levels of beef silver skin (0%, 5%, and 10%) were then included to create meat emulsion with incremental levels of collagen. The emulsions were prepared in a bowl chopper at 1,725 rpm for 9 min. A total of 27 emulsions were created by combining the 3 pork sources, 3 levels of silver skin, and 3 replicates. Immediately after chopping, the emulsion was measured for temperature, pH, water activity, and raw emulsion color. In addition, 29 g of the emulsion was stuffed into four 50 mL centrifuge tubes and cooked in a water bath at 70°C for 30 min. The fat and water loss were recovered and computed while the cooked emulsion was evaluated for texture profile. Raw meat emulsions were also analyzed for collagen content. Data were analyzed using the PROC MIXED of SAS including the fixed effect of treatment (silver skin level) and random effects of pork source and replicate. Pearson correlations among variables were also calculated.

Results: Silver skin inclusion linearly increased collagen concentration in the emulsion ($P < 0.001$). The raw emulsion water activity, pH, and instrumental color were not affected by silver skin level ($P > 0.05$). The inclusion of silver skin linearly increased fat loss in cooked emulsion ($P = 0.02$). Cooked emulsion hardness, springiness, and chewiness decreased ($P < 0.01$) as silver skin level increased. Low Pearson correlation coefficients ($r < 0.2$; $P > 0.05$) was found between emulsion collagen concentration and cooked emulsion texture or fat loss.

Conclusion: The increased fat loss and reduced texture profile parameters suggest that including silver skin reduces emulsion stability and product yield.

Funding Source: Gatton Academy and Western Kentucky University (Quick Turnaround Grant).

Keywords: collagen, emulsion stability, meat emulsion, silver skin, texture profile

## 25 PHYSICOCHEMICAL PROPERTIES AND TENDERNESS OF MARINATED PORK LOIN INJECTED WITH GOLD AND GREEN KIWI EXTRACTS DURING INCUBATION TIME

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Objectives: This study was performed to evaluate physicochemical properties and tenderness in pork loin injected with 10% and 20% gold and green kiwi extracts during incubation at 10°C for 24 h.

Materials and Methods: Gold kiwi (*Actinidia chinensis* var. *chinensis* "Zesy002") and green kiwi (*Actinida deliciosa* var. "Hayward Green") were used in this study. After the gold and green kiwifruits were homogenized with 20 mM phosphate buffer (pH 6.5) and centrifuged at $10,000 \times g$ for 15 min, the supernatant of kiwi mixture was taken and used for this experiment. Gold and green kiwi extracts were injected at 10% and 20% of the original weight of the pork loin cuts, which were measured for the physicochemical and textural properties during incubation at 10°C for 24 h. Before cooking, pH and color (CIE $L^*$, $a^*$, $b^*$) values, myofibrillar fragmentation index (MFI), solubility of peptides in trichloroacetic acid (TCA), and sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) were measured at 0, 4, 8, and 24 h of incubation at 10°C. After cooking, pH and color values, cooking loss (CL; %), Warner-Bratzler shear force (WBSF; kg/g) values, and scanning electron microscope (SEM) were measured. The whole experiment was performed 3 times, and the statistical analysis was performed via two-way analysis of variance (treatment × incubation times at 10°C) at a significant level of 0.05%.

Results: Before cooking, the pork loin cuts injected with kiwi extracts showed lower pH values than CTL, regardless of levels of addition. TCA solubility and MFI values of pork loin containing 10% of green kiwi extract were similar to those of pork loin injected with 20% of gold kiwi extract. When kiwi extract was injected into pork loin, the tenderness increased with the increased incubation time up to 24 h. These results were confirmed by decreased myosin heavy chain (MHC) band of the SDS-PAGE. After cooking, the pork loin cuts injected with kiwi extracts showed lower pH values than CTL, whereas the injection of kiwi extracts into pork loin did not affect the color of cooked pork loin. Regardless of the color of kiwi, pork loins injected with 20% kiwi extracts had a higher CL (%) than the CTL. A decrease in WBSV was observed when the kiwi extract was injected into pork loin, regardless of the level of

addition. It can be confirmed that unlike the injected pork loin, control pork loin had well-organized and tightly arranged muscle fibers for all incubation times, and there was no rupture in the structure of the muscle fibers in SEM.

Conclusion: Green kiwi had higher tenderizing ability than gold kiwi even when 10% injection was applied to pork loin. Although 20% injection improved tenderness of pork loin better than 10% injection, it might cause problems related to the increased CL. Thus, 10% injection of green kiwi extracts into pork loin might be recommended for use in meat as a tenderizing agent and for maintaining agent and water-holding capacity.

Funding Source: This work was supported by Kiwifruit Export Research Organization, Chonnam National University, Gwangju, Republic of Korea.

Keywords: gold and green kiwi extract, incubation, marinated, pork loin, tenderness

## 26 EFFICACY OF NOVEL BIOPOLYMERIC EDIBLE FILM TO CONTROL TYROPHAGUS PUTRESCENTIAE GROWTH IN DRY-CURED HAMS

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Objectives: Dry-cured ham, produced and consumed worldwide, is susceptible to infestations of *Tyrophagus putrescentiae* (ham mites), which has a zero tolerance in the product. Methyl bromide (MB) fumigation was previously used to control ham mites and prevent adulteration of dry-cured hams; MB is no longer available for fumigation because it is a Class I ozone depleting substance. Previous research demonstrated that food-grade coated polyester nets can reduce mite infestations and may be a viable replacement to MB. Biodegradable/edible films offer an environmentally friendly alternative to both MB and coated nets because of their cost-efficiency and feasibility. The goal of this research was to determine the efficacy of a novel biopolymeric edible film to reduce ham mite growth and reproduction.

Materials and Methods: The biopolymeric films' ingredients consist of water with confidential materials: compound X and compound Y. Compound X was tested in edible films at increasing concentrations labeled sequentially C to G. Compound Y was kept at a constant concentration for all treatments of compound X at each of the concentrations C-G. Ingredients were solubilized in water and sheared (400 rpm) over a hot plate until the resulting solution was homogenous. The solution (30 mL) was then cast onto 100 mm plastic Petri dishes and dried at 25°C and 50% relative humidity for 72 h. Ham cubes (15.625 $cm^3$) were prepared from whole dry-cured hams and stored in the refrigerator (2°C to 4°C) before testing. The resulting films' effectiveness at controlling ham mites were then tested against 2 control treatments: exposed nonfilmed ham cubes (negative control; A) and ham cubes wrapped in coated polyester nets (positive control; B). The treatments therefore consisted of the negative control (A), positive control (B), remaining treatments with one concentration of compound Y with concentration(s) X1 (C), X2 (D), X3 (E), X4 (F), and X5 (G). Films (treatments C-G) were carefully removed from the Petri dishes and wrapped around the ham cubes (15.625 $cm^3$). Each cube was then inoculated with 20 adult, mixed-sex mites. Inoculated ham cubes ($n = 5$/trt) were incubated in ventilated jars at 25°C and 75% relative humidity for 14 d before the active mites were counted under a microscope for each jar. A randomized complete block design with 2 replications was used to determine the efficacy of treatments at controlling mite reproduction. Tukey's Honestly Significant Difference test was used to separate treatment means when differences existed ($P < 0.05$) among treatments.

Results: All film treatments (C-G) and positive control (B) had fewer ($P < 0.05$) mites than the negative control (A; 266 mites). No other differences existed ($P > 0.05$). Mite counts for treatments F (8 mites) and G (2 mites) were comparable with that of the positive control (B; 1 mite), with all of them being under the initial inoculation number of 20 mites, indicating efficacy of the films to inhibit mite reproduction. Treatments C (28 mites), D (28 mites), and E (21 mites) clearly slowed mite population growth and reproduction.

Conclusion: In conclusion, the film treatments consisting of ingredients X and Y could control mite infestations, with the efficacy dependent on the concentration of compound X. Further research should be conducted to determine moisture loss of ham overtime, sensory effects, in-plant efficacy, and ability to formulate film on a large scale.

Funding Source: USDA Methyl Bromide Transition Program Project 2021-04368.

Keywords: dry-cured ham, edible films, food-grade coatings, methyl bromide, *Tyrophagus putrescentiae*

## 27 EVALUATING THE EFFECT OF ACCELERATED AGING AT DIFFERENT TEMPERATURE AND TIME POINTS ON TENDERNESS, YIELD AND AEROBIC PLATE COUNT OF LOWER QUALITY BEEF CUTS

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Objectives: As the current price of beef continues to rise, consumers are keener in searching for alternative beef cuts with lower price points to replace the traditional middle beef cuts. Accelerated aging (AA) is a new meat tenderization methodology that entails incubating vacuum-packaged meat in a warm water bath to enhance the enzymatic activity and accelerate the tenderization process. However, there is no documentation of the actual efficacy of AA on meat quality. Therefore, the objective of this study was to evaluate the impacts of 4 different AA temperature and time points on meat tenderness, yields, and microbial quality on 2 lower quality beef cuts.

Materials and Methods: *Triceps brachii* (TB) and *semimembranosus* (SM) were obtained from 10 USDA choice beef carcasses. Each muscle was cut into 2.54 cm steaks at 3 d postmortem, vacuum packaged, and subjected to 1 of 6 treatments: (1) 3 d postmortem (control); (2) 21 d 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, where the last 4 treatments were incubated in 10 separate sous vide systems for the AA process. It is important to note that the AA process does not "cook" the steaks. Yield calculations were based on loss during the AA treatments and cooking loss. Purge was collected from each primal bag as well as from each vacuum package containing the steak after the AA treatments. Steak surface was swabbed on one side prior to AA treatments and swabbed on the other side after AA treatments. Aerobic plate count (APC) was performed on both purge and swab samples. Finally, all steaks from the 6 treatments were cooked on a griddle until they reached an internal temperature of 71°C, and Warner-Bratzler shear force (WBSF) was measured for each cooked sample.

Results: All 4 AA treatments improved in tenderness compared with the control ($P < 0.01$). The AA 54°C for 3 h, AA 54°C for 2 h, and AA 49°C for 3 h treatments all had similar tenderness as the 21 d aging treatment ($P > 0.05$). Regardless of muscles and treatment time, AA 49°C groups had greater yield after AA than AA 54°C groups. On the other hand, TB had greater yield after AA than SM groups regardless of AA temperature and times ($P < 0.05$). All 4 AA treatments produced higher cooking yields than the 3 d and 21 d aging treatments ($P < 0.01$). Finally, TB had greater cook yield compared with that of SM ($P < 0.01$). When observing the microbial results of purge, all post-AA purge samples regardless of muscles had less APC than purge from the subprimal bags ($P < 0.01$). Interestingly, the APC was higher in the purge from the shoulder clods than the top rounds ($P < 0.01$). Finally, the APC results of the swabs indicated post-AA significantly decreased the APC compared with pre-AA treatments ($P < 0.01$).

Conclusion: This study indicated that all AA treatments improved beef tenderness and decreased APC compared with the control, with most AA treatments being as effective as 21 d cooler aging in tenderness improvement. It is interesting to note that less water was lost during cook yield measurement for AA treatment samples, which is likely due to most of the free water having been released during the AA treatments. Further studies are needed to investigate the underlying mechanisms of AA to have a better handle on the enzymatic activity during different temperature and time periods.

Funding Source: Kansas Beef Council.

Keywords: aging, aerobic plate count, cook yield, Warner-Bratzler shear force

## 28 THE EFFECTS OF GRIND PLATE SIZE, BLEND TIME, AND PATTY-FORMING EQUIPMENT ON GROUND BEEF TEXTURE

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Objectives: Consumers recognize texture as an important characteristic that contributes to the satisfaction of chewing and the pleasure of eating ground beef. The vast majority of the research conducted on texture up to this point has been in regard to tenderness of whole muscle cuts, whereas few researchers have studied texture in ground beef. The objective of this study was to evaluate the effects of grind plate size, blend time, and patty-forming technique on ground beef texture as quantified by descriptive sensory analysis and objective measurement.

Materials and Methods: Beef chuck trimmings (81% lean, 19% fat) were randomly assigned to 1 of 12 treatment combinations between 2 grinder plate sizes (3.18 or 1.59 mm), 3 mixing times (1.5, 3, or 4.5 min), and 2 patty-forming devices. The trimmings were ground within 5 d of box date. Each batch was ground using a coarse grinding plate (12.7 mm) and was mixed for its specified time. During the first 1.5 min of mixing, $CO_2$ was continuously added to the mixer until approximately −1°C. Following mixing, batches were ground a second time using the same grinder equipped with its designated fine-grinding plate. Each batch was then formed into patties weighing 151 g using either a Formax (Formax F6, equipped with the 2874-6 plate, Mokena, IL) or a vacuum stuffer (Model VF50, Handtmann, Germany) equipped with a portioning device. Patties from each batch were $CO_2$ blast frozen, randomly sorted, vacuum packaged, and placed in frozen storage (−20°C) for further analysis. All samples were cooked to an internal temperature of 71°C on a stove top using griddle pans with nonstick coating heated to 204°C. Trained sensory panelists evaluated ground beef patties for 7 different texture characteristics including hardness, cohesiveness, tenderness, connective tissue, particle size, moisture content, and beef fat/oily mouthfeel. For objective texture measurements, a 3.8-cm × 3.8-cm square piece was cut from the middle of the cooked patty and placed in the

CT3 Texture Analyzer equipped with the Fixture Base Table and Ottawa Cell.

Results: The interactions of grind size, mix time, and patty-forming technique were not significant ($P > 0.05$). Perceived texture differences existed between the grinder plate size and patty-forming technique. Panelists indicated that ground beef patties produced with smaller-sized grind plates were softer and more tender and had a smaller particle size ($P < 0.01$). In agreement, objective measures of texture showed lower peak loads for patties produced with smaller-sized grind plates ($P < 0.01$). Detectable differences also existed in ground beef patties fabricated with different patty-forming techniques. Patties made with a Formax were softer and more cohesive, whereas patties made with the Vacuum Stuffer equipped with a portioning device were crumblier but also ranked higher for moisture content and oily mouthfeel ($P < 0.01$). The objective measures of patty formation showed the Formax exhibited a greater peak load ($P = 0.045$). The long mixing time showed a greater moisture content ($P = 0.037$). However, no other differences existed due to mixing time ($P \geq 0.107$).

Conclusion: The grind size and patty formation technique of the patty affected the overall eating experience. Further research is necessary to determine the desirability of these differences and their potential for premium marketing opportunities.

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

Keywords: patty, beef trimmings, grind, ground beef

## 29 FREEZE/THAW CYCLES AND ENZYMATIC TREATMENT DO NOT IMPACT TEXTURE OR TENDERNESS OF BEEF BRISKET

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Objectives: The objective of this research was to investigate the effect of multiple freeze-thaw cycles on brisket and to explore if using a meat tenderizer product would compound any changes in tenderness. We hypothesized that subjecting beef briskets to multiple freeze and thaw cycles would improve instrumental tenderness of cooked brisket.

Materials and Methods: Briskets ($n = 15$) collected from cattle slaughtered at the South Dakota State University Meat Lab were aged for 21 d and randomly assigned to 1 of 3 treatments: 1 freeze-thaw cycle (1FT, $n = 5$), 2 freeze-thaw cycles (2FT, $n = 5$), or 2 freeze-thaw cycles coupled with an application of tenderizer (TEND, $n = 5$). All briskets were weighed after collection, vacuum packaged, frozen, and stored at −20°C for approximately 6 mo before the treatments were applied. Weights varied between 6 and 10 lb for each brisket. Briskets were thawed at 4°C for 72 h. The 1TF group did not receive any more treatment and were vacuum packaged and held at 4°C until the other treatment groups were ready to be cooked (72 h total hold time). The 2TF group was repackaged and frozen a second time at −20°C for 24 h. The TEND group received an application of Adolf's Meat Tenderizer according to label instructions (9.33 g tenderizer/kg, active ingredient: bromelain), was repackaged, and was frozen for a second time at −20°C for 24 h. The 2 freeze-thaw cycles groups were thawed at 4°C for 48 h before cooking. Briskets and vacuum bags were patted dry and weighed to determine purge loss. All briskets were cooked in the same smokehouse cycle and held at 76°C for 20 h after the smoking step. All briskets were cooled to room temperature (20°C) and reweighed to determine cook loss. The flat portion of the brisket was removed after cooking and split into 3 sections, which were allocated to either standard Warner-Bratzler shear force (WBSF), star probe parallel to the muscle fibers, or star probe perpendicular to the muscle fibers. The briskets were refrigerated at 4°C for 24 h and then equilibrated to room temperature. Five 1.27 cm cores were collected from the strip designated for WBSF and sheared perpendicular to the fibers. Star probe was evaluated at 5 locations on each section in accordance to the fiber direction assignment. Star probe values were measured at 80% of original sample height. Shear force and star probe values were calculated by averaging all 5 readings from the respective sections. Shear force, star probe, purge loss, and cook loss were analyzed for the effect of freeze-cycle treatment using the MIXED procedure of SAS.

Results: No treatment effect was observed for purge loss, WBSF values, parallel star probe values, or perpendicular star probe values ($P > 0.0001$). A treatment effect for cook loss was observed with 1FT briskets having less cook loss than both other treatments. The 1FT group had less ($P < 0.0001$) cook loss when compared with the 2FT and TEND groups (39.4% vs. 44.6% and 46.6%, respectively).

Conclusion: The number of freeze-thaw cycles the briskets underwent had no effect on instrumental tenderness. However, multiple freeze-thaw cycles resulted in an increased cook loss of the brisket. Also, application of meat tenderizer did not affect tenderness of the brisket. Additional research into multiple freeze-thaw cycles is needed to determine how this may influence beef brisket quality.

Keywords: beef, brisket, freeze-thaw cycle, tenderness

## 30 RESIDUAL NITRITE AS A BASELINE FOR ASSESSING THE ABILITY OF THE NITRIC OXIDE SYNTHASE SYSTEM TO GENERATE NITRITE OXIDE WITHOUT A CURE ACCELERATOR

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Objectives: This study will compare with a prior study that included sodium erythorbate (NaE) in same sample parameters (species, temperature, concentration) and resulted in lower residual nitrite ($RNO_2$) and nitrosylhemochromagen (NO-H) values. It will assess the ability of the nitric oxide synthase (NOS) system activated by L-arginine HCl (L-arg) to generate nitric oxide (NO) and $RNO_2$ compared with sodium nitrite ($NaNO_2$)-treated beef, pork, and poultry samples without NaE.

Materials and Methods: Ground beef and pork (80/20) and poultry (97/3) batches were mixed with 2% salt and 10% water ($N = 9$) and split into 454 g batches. Each batch was blended with Prague powder ($NaNO_2$) to achieve 120, 156, or 200 ppm $NaNO_2$ or with L-arg for 1,000; 2,000; 3,000; 4,000; or 5,000 ppm concentrations (C) with no added NaE as used in a prior study. After mixing (1 min) 25 g samples were extruded into two 50 mL centrifuge sample tubes. Sample tubes ($NaNO_2$ $N = 18$; or L-arg $N = 30$) were placed in a controlled water bath and cooked to 55.6°C, 70.0°C, or 73.9°C (T). Samples were chilled and stored (2°C) for 7 d. $RNO_2$ (UV/VIS spectrophotometry) and nitrosylation (NO-H formation) were analyzed. The experiment was a factorial (3 $NaNO_2$ or 5 L-arg C and 3 T with 2 samples per C) randomized complete block design. This resulted in 18 ($NaNO_2$) or 30 (L-arg) sample tubes per rep for each species and repeated 3 times. Least-squares means were generated and Tukey's HSD used with a predetermined $P < 0.05$ significance.

Results: Neither C or T had an effect on $RNO_2$ levels in $NaNO_2$ beef samples ($P < 0.1$). A CxT interaction ($P < 0.05$) existed for $NaNO_2$ pork and poultry samples, with higher $RNO_2$ values observed at 200 ppm and 73.9°C. All L-arg samples showed a CxT ($P < 0.05$) interaction. As C increased to 4,000 ppm and T increased to 70°C, greater $RNO_2$ were observed, whereas lower values were observed at 73.9°C and 5,000 ppm in beef L-arg samples. Pork L-arg samples had higher $RNO_2$ at 70°C and 3,000 ppm, with lower values at 73.9°C and 4,000 ppm. Poultry L-arg samples had more $RNO_2$ at 55.6°C and 2,000 ppm, then decreased at 3,000 ppm and 73.9°C. $RNO_2$ levels were lower for all L-arg samples than $NaNO_2$ samples. In a prior study, $NaNO_2$ and L-arg–treated pork samples had lower $RNO_2$ values (61 and 71 ppm, respectively) than this study (198 and 87 ppm, respectively). The main effects of C ($P < 0.05$) and T ($P < 0.0001$) decreased NO-H values in beef $NaNO_2$ samples. In pork $NaNO_2$ samples, NO-H decreased as C ($P < 0.0001$) and T ($P < 0.05$) increased. In poultry $NaNO_2$ samples, NO-H levels were higher at C ($P < 0.005$) 200 ppm and T ($P < 0.05$) 70°C. L-arg beef samples had more NO-H at 4,000 ppm ($P < 0.0005$) and 55.6°C ($P < 0.001$). A CxT interaction ($P < 0.0001$) in pork L-arg samples showed greater NO-H at 4,000 ppm and less at 73.9°C. NO-H values of poultry L-arg samples decreased ($P < 0.05$) as T increased. All $NaNO_2$ and L-arg samples contained lower NO-H values. Prior study $NaNO_2$ and L-arg–treated pork samples NO-H levels were higher (10.7 and 6.7 ppm, respectively) than this study (6.7 and 1.4 ppm, respectively).

Conclusion: L-arg samples at 1,000 to 4,000 beef, 1,000 to 3,000 pork, and 1,000 to 2,000 ppm poultry had lower $RNO_2$ levels than $NaNO_2$ samples at 120, 156, and 200 ppm in the absence of NaE. These values were higher for samples containing NaE, whereas NO-H values were lower. This study indicates NaE is needed to promote NO-H formation and $RNO_2$ via the NOS system.

Keywords: cured meats, L-arginine, nitric oxide, sodium erythorbate, sodium nitrite

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## 31 IMPROVE LUTEIN CONTENT IN EMULSION TYPE BEEF PRODUCTS BY ADDING LUTEIN-LOADED ALGINATE/ CHITOSAN COMPLEX

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Objectives: Lutein is mainly found in various fruits, green leafy vegetables, and egg yolk. Lutein possesses multiple functions in the human body. The intake of lutein at 6 to 20 mg/d can reduce the occurrence of AMD and cataracts by up to 50% (Alves-Rodrigues and Shao, 2004). However, the current average intake of lutein ranges from 1.7 to 2.2 mg/d for Americans and Europeans, far below the functional level of 6 to 20 mg/d (O'Neill et al., 2001). The low intake of green leafy vegetables contributes to the low intake of lutein in the Western diet. Currently, the development of lutein-enriched foods is getting more attention because of their potential in helping increase the intake of lutein. However, lutein is unstable to general meat processing conditions, such as high temperature, light, and oxygen, which hindered its application in lutein-enriched meat production. Our goal was to stabilize lutein by loading it into an alginate/chitosan complex and investigating its application to increase lutein content in meat products.

Materials and Methods: Materials: Sodium alginate, chitosan, calcium chloride, lutein, ground beef. Methods: Lutein-loaded alginate/chitosan complex was produced by coacervation. Ethanolic lutein solution was prepared at 0.16%, and alginate and chitosan working solution were

0.01%, respectively. Lutein solution was added to alginate solution under mild stirring, followed by adding chitosan. The pH of this mixture was adjusted to 6.0. The ratio of alginate:chitosan was 3:2, short as 3AL/2CS. The ratio of 3AL/2CS: lutein was 25:4. Lutein-loaded complex produced under this condition short as 3AL/2CS/LU. In beef production, free lutein and 3AL/2CS/LU was added to beef and emulsified 2 min using a lab scale blender. No lutein added group was made as control. 2% NaCl was added to facilitate beef emulsification. In both free lutein and 3AL/2CS/LU groups, lutein was added at 200 ppm. The beef batters were stuffed into a 30 mm collagen casing and cooked in a convection oven until internal temperature reach to 160°F, followed by packaging in an oxygen-permeable plastic bag and stored in a cooler (2°C to 4°C) for 5 d. Lutein content and lipid oxidation were measured ($n = 3$). The results were reported as averages and standard deviations. Two-way *t* test was applied to compare the mean values. A $P$ value of $< 0.05$ was considered statistically significant.

Results: After 5 d of storage, the lutein content in beef is $590.20 \pm 35.78$ mg/100 g of meat, which is about 30% of added lutein remained. There was no significant ($P = 0.19$) difference in malondialdehyde (MDA) content among the 3 groups on the cooked day. However, after 1-d storage, the MDA content in the control group was rapidly increased ($2.95 \pm 0.10$ μg MDA/Kg muscle) and significantly higher than that in free lutein and 3AL/2CS/LU groups, which was $2.51 \pm 0.22$ and $2.23 \pm 0.20$ μg MDA/Kg muscle respectively. The lower MDA content in both lutein added groups came from the antioxidative properties of lutein. With the increasing storage period, the difference in MDA content among those 3 groups decreased and there was no significant difference on the fifth day. This result was due to the pro-oxidative factors in cooked beef, which exceeded the antioxidant activity of lutein.

Conclusion: Lutein-enriched beef products can be produced by adding a lutein-loaded complex. An antioxidant is required for longer storage stability.

Funding Source: Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa.

Keywords: alginate, beef, chitosan, coacervation, lutein

## *32 EVALUATION OF ANTIOXIDANT ACTIVITIES OF OVEN-DRIED LOTUS RHIZOME ROOT POWDER WITH DIFFERENT EXTRACTION CONDITION AND ITS APPLICATIONS TO LOW-FAT PORK SAUSAGES AS A FUNCTIONAL INGREDIENT*

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Objectives: The objective of this study was to evaluate the antioxidant activities of 100°C oven-dried lotus rhizome root powder (ODLRRP) and its ethanolic extract (ODLRRPE) as affected by various ethanol concentrations (0%~100%) and extraction times (0~8 h) and determine the best antioxidant activity among ethanol levels and extraction times. In a 2nd study, the 1% ODLRRP and 0.1% ODLRRPE were added to low-fat pork sausages (LFPSs), respectively, and the physicochemical properties and shelf-life effect were evaluated during refrigerated storage if they have antioxidant and antimicrobial activity during storage.

Materials and Methods: Lotus rhizome roots (LRRs) were chopped into slices (3 cm, thickness) and dried at 100°C for 8 h until the weight was constant. After the dried slices were pulverized into a powder with a particle (< 150 μm), ODLRRP was extracted with various ethanol concentrations (0%, 25%, 50%, 75%, 100%) and extraction times (0, 2, 4, 6, 8 h). For the measurement of antioxidant activity, total phenolic compounds, 1,1-diphenyl-2-picrylhydrazyl radical-scavenging activity (DPPH), reducing power, and ferrous iron chelating ability were measured. For the manufacture of sausages, pork hams were ground and mixing with ingredients. Mixed meat batter was stuffed into cellulose casings. Then, the sausages were smoked and cooked until the internal temperature reached 72°C. After they were chilled, all sausages were peeled and vacuum packaged, and they were stored at 10°C ± 1°C for 35 d until analyzed. During refrigerated storage, physicochemical properties and shelf-life effect of LFSs were evaluated. The whole experiment was performed triplicates. For the antioxidant activity, one-way analysis of variance (ANOVA) was performed, with 5 ethanol levels or extraction times as a factor, whereas the experimental design of sausage application was performed as 2-way ANOVA (treatment × storage time) at the significant level of 0.05.

Results: Antioxidant activity of ODLRRPE were higher than ODLRRP and the control, whereas 4 h extraction had similar antioxidant activity to those with 6 or 8 h. The pH of boiling sausages with 1% ODLRRP was reduced compared with control sausages (CS). The sausages tended to be darker with the addition of ODLRRP or ODLRRPE; however, their redness and yellowness were increased with the addition of the powders, regardless of extraction. The addition of 1% ODLRRPE into LFSs decreased textural hardness and gumminess. Lipid oxidation did not retard with the addition of either 1% ODLRRP or 0.1% ODLRRPE, whereas 0.1% ODLRRPE addition to LFSs reduced the microbial counts from 4 wk of storage.

Conclusion: Antioxidant activity was best at 50% ethanol and for 4-h extraction time as compared with other ethanol concentration and extraction time. The addition of 1% ODLRRP or 0.1% ODLRRPE into LFPSs tended to be darker, whereas the addition of 0.1% ODLRRPE alone inhibited the microbial growth, as compared with the control.

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Keywords: antioxidant activity, ethanolic extract, low-fat sausages, oven-dried lotus rhizome root powders, physicochemical properties

### 33 DEVELOPMENT OF VOLATILE FLAVOR COMPOUNDS IN WET PET FOOD PROCESSED AT DIFFERENT RETORT PARAMETERS

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Objectives: The objective of this study was to identify volatile compounds produced in wet pet food products processed under varying retort conditions.

Materials and Methods: Eighty-five gram canned wet pet food diets were produced in a commercial facility. Diet formulations were the same. Cans underwent thermal processing under 2 retort conditions: 117.8°C for 55 min (CNTL) and 121°C for 44.48 min (TEST). Cans were then shipped overnight to Texas Tech University (TTU). Additionally, nonthermal processed samples (RAW) were shipped frozen to TTU. RAW samples were kept frozen at −20°C until analysis. Both CNTL and TEST samples were stored at ambient temperature. Volatile compound analysis was conducted using gas chromatography–mass spectrometry (GC-MS). RAW samples were thawed prior to volatile analysis. Volatile compounds were extracted using solid phase microextraction (SPME). Volatiles were extracted for 25 min then injected into the GC-MS. Samples were analyzed in duplicate. Volatiles were quantitated (ng/g) using a 5-level calibration curve. Data were analyzed as a completely randomized design. An alpha of 0.05 was used to determine significance.

Results: Two compounds were different between the TEST and CNTL samples ($P < 0.001$). Benzene and α-pinene concentrations were greater in TEST samples compared with CNTL ($P < 0.001$). TEST samples tended to have a greater concentration of 3-methyl-thiophene compared with CNTL ($P = 0.088$). Of the 84 identified compounds, 44 were different between raw and thermally processed samples ($P < 0.05$). Decane, nonane, tetradecane, octanoic acid, methyl butyrate, methyl octanoate, methyl hexanoate, heptanal, hexanal, pentanal, and dimethyl-disulfide were produced in greater concentrations in RAW samples compared with TEST and CNTL samples ($P < 0.05$). CNTL and TEST had greater concentrations of ethanol, 2-butanone, 2-heptanone, 2-pentanone, 2-propanone 2,3-butanedione, benzaldehyde, butyraldehyde, acetic acid, 2-methylbutanal, methional, phenylacetaldehyde, styrene, α-pinene, ethylbenzene, benzene, nonane, 1-hexanol, 1-octanol, 1-pentanol, 1-penten-3-ol, methanethiol, 3-methyl-thiophene, 2-methyl-3-furanthiol, dihydro-2-methyl-3-(2H)-furanone, 2-pentyl furan, methylpyrazine, 2,5-dimethylpyrazine, 2-ethyl-3,5/6-dimethylpyrazine, furfural, 5-methylfurfural, furfuryl alcohol, and diallyl sulfide compared with RAW ($P < 0.05$).

Conclusion: These data indicate retort conditions minimally influenced volatile compound development. Thermal processing increased volatile compounds associated with lipid degradation and the Maillard reaction. Additionally, volatile compound analysis has the potential to be applied to the development of pet food products.

Funding Source: Simmons Foods.

Keywords: flavor development, pet food, retort, volatiles

## Meat and Poultry Quality

### 34 INFLUENCE OF END-POINT COOKING TEMPERATURES ON THE DEGRADATION OF DESMIN IN PORK LONGISSIMUS DORSI MUSCLE DURING EXTENDED PERIODS OF POSTMORTEM AGING

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Objectives: Lowering end-point cooking temperatures (i.e., degree of doneness) when preparing pork has been shown to improve pork eating satisfaction. The degradation of cytoskeletal and intermediate filament proteins, like desmin, is known to play an important role in postmortem tenderization processes. Nonetheless, research that investigates the impact of extended postmortem aging in combination with end-point cooking temperature on protein degradation is limited and should be revisited. Therefore, the objective of this study was to examine the influence of aging and end-point cooking temperatures on desmin degradation in pork chops.

Materials and Methods: Pork *longissimus dorsi* ($n = 24$) samples from 3 different genetic sire-lines were obtained from a commercial packing plant. The muscles were divided into 2 sections and randomly assigned to postmortem aging (wet aging at 2°C) for either 14 or 21 d. After each postmortem aging period elapsed, each muscle section was fabricated into two 2.54-cm-thick pork chops and randomly allotted to an internal end-point cooking temperature of either 63°C or 71°C using a water bath before Warner-Bratzler shear force (WBSF) and cooking loss were evaluated. Whole muscle protein was extracted from each of the cooked muscle samples and subjected to SDS-PAGE. Desmin concentration was determined via western blot using the iBlot 2 protocol for gel transfer, antibody binding,

**Table 1.** Influence of aging and end-point cooking temperature on cooked chop traits and desmin degradation

| | Aging-14d | | Aging-21d | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|
| Items | 63°C | 71°C | 63°C | 71°C | SEM | Aging | Temp | Aging × Temp |
| Cooking loss, % | 11.80$^{ay}$ | 18.94$^{ax}$ | 9.06$^{by}$ | 15.24$^{bx}$ | 0.47 | 0.02 | <0.01 | 0.32 |
| Warner Bratzler shear force, kg | 1.75$^{y}$ | 2.34$^{x}$ | 1.98$^{y}$ | 2.57$^{x}$ | 0.10 | 0.13 | <0.01 | 0.97 |
| **Desmin concentration** | | | | | | | | |
| Total desmin | 2.56 | 2.93 | 2.93 | 2.69 | 0.18 | 0.76 | 0.72 | 0.09 |
| Desmin degradation rate | 0.95$^{b}$ | 0.94$^{b}$ | 0.97$^{a}$ | 0.96$^{a}$ | 0.01 | 0.05 | 0.09 | 0.94 |
| Intact desmin (53kDa) | 0.05$^{a}$ | 0.06$^{a}$ | 0.03$^{b}$ | 0.04$^{b}$ | 0.01 | 0.05 | 0.09 | 0.94 |
| Degraded desmin (42kDa) | 0.25$^{y}$ | 0.31$^{x}$ | 0.26$^{y}$ | 0.28$^{x}$ | 0.01 | 0.48 | 0.01 | 0.10 |
| Degraded desmin (38kDa) | 0.70$^{x}$ | 0.63$^{y}$ | 0.71$^{x}$ | 0.69$^{y}$ | 0.02 | 0.16 | 0.01 | 0.19 |

$^{a–b}$Means with different letters are different in the same row (effect of aging; $P < 0.05$).

$^{x–y}$Means with different letters are different in the same row (effect of temperature; $P < 0.05$).

imaging, and quantification. Instrumental tenderness was measured on 1.3-cm-diameter cores that were cut parallel to muscle fibers. Cooking loss, WBSF, and desmin concentration were analyzed as a split-plot design, with aging time as a whole-plot factor and end-point cooking temperature as a subplot factor. Genetic sire-line was considered as a random effect. The data were analyzed using PROC GLIMMIX and PROC CORR of SAS.

Results: Desmin degradation rate (desmin degradation products/total desmin) was increased by aging ($P < 0.05$; Table 1). An increase in end-point cooking temperature from 63°C to 71°C tended to increase ($P = 0.09$) desmin degradation rate. The abundance of intact desmin (53 kDa) decreased ($P < 0.05$) upon aging. The 42 kDa desmin degradation products were increased ($P < 0.05$) as end-point cooking temperature increased from 63°C to 71°C. By contrast, pork chops cooked to an end-point temperature of 63°C demonstrated greater ($P < 0.05$) abundance of the 38 kDa desmin degradation products than those cooked to 71°C. Cooking loss was influenced ($P < 0.05$) by both aging and end-point cooking temperatures, whereas WBSF was only influenced ($P < 0.05$) by end-point cooking temperatures. Total desmin abundance (sum of intact and degraded desmin) was not significantly influenced by aging ($P > 0.05$) or end-point cooking temperatures ($P > 0.05$). Nevertheless, desmin degradation rate was weakly correlated with the WBSF ($r = 0.11$; $P = 0.33$).

Conclusion: Desmin degradation rate was influenced by extended periods of postmortem aging. Surprisingly, different end-point cooking temperatures resulted in different abundance of desmin degradation products. Therefore, this study suggested that end-point cooking temperature might influence pork tenderness by altering levels of protein degradation. Further studies are warranted to determine the interactive roles of aging and end-point cooking temperatures in other myofibrillar proteins.

Keywords: desmin, end-point cooking temperature, pork quality, postmortem aging, tenderness

## *35 AN EVALUATION OF THE INTERACTIVE EFFECTS OF FREEZE-THAW CYCLES AND END-POINT COOKING TEMPERATURE ON COOKING LOSS AND INSTRUMENTAL TENDERNESS OF PORK LONGISSIMUS DORSI MUSCLE*

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Objectives: Repeated freezing and thawing of meat may occur in both food service and retail settings as well as at the consumer level. Freeze-thaw events can lead to physiological and biochemical damage in muscle systems, including loss of product quality that is related to purge loss, discoloration, and protein degradation. It has been suggested in recent years that end-point cooking temperature plays a very meaningful role in consumer eating satisfaction of fresh pork. Yet, there are limited data on the influence of freezing and thawing events in combination with end-point cooking temperature. Thus, the objective of this study was to evaluate the interactive effects of freeze-thaw cycles and end-point cooking temperature on instrumental tenderness of pork *longissimus dorsi* muscle.

Materials and Methods: Pork *longissimus* muscles ($n = 64$) from 8 different genetic sire-lines were obtained from a commercial packing plant. The muscles were divided into 3 sections and randomly assigned to 0 (CON), 1 (FT1), or 2 (FT2) freeze-thaw events. CON samples were allotted to wet aging for 21 d. FT1 samples underwent one freeze-thaw event after 14 d of postmortem aging and further aged for 7 d. FT2 samples were aged for 14 d, experienced one freeze-thaw event at day 14, and then were aged for 7 additional days before another freeze-thaw event. During each freeze-thaw event, samples were placed in single layer on a plastic tray in a −30°C freezer for at least 12 h before thawing at 2°C for 24 h. Each muscle section was further fabricated into 2 pork chops and randomly allotted to an internal end-point

**Table 1.** Effect of freeze-thaw events on cooking loss and Warner Bratzler shear force (WBSF) of cooked pork

| | Treatments[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CON | | FT1 | | FT2 | | | |
| | 63°C | 71°C | 63°C | 71°C | 63°C | 71°C | SEM | *P*-value |
| Cooking loss, % | 8.90$^{c}$ | 14.83$^{b}$ | 9.66$^{c}$ | 14.71$^{b}$ | 9.28$^{c}$ | 17.28$^{a}$ | 0.47 | <0.01 |
| WBSF, kg | 1.87$^{cd}$ | 2.31$^{a}$ | 1.85$^{d}$ | 2.06$^{bc}$ | 1.68$^{d}$ | 2.13$^{ab}$ | 0.06 | 0.02 |

$^{a–d}$Means with different letters are different in the same row ($P < 0.05$).

[1]CON: zero freeze-thaw events; FT1: one freeze-thaw event; FT2: two freeze-thaw events.

cooking temperature of either 63°C or 71°C using sous vide cooking techniques in a water bath. Cooking loss and Warner-Bratzler shear force (WBSF) were determined following cooking. Purge loss data were analyzed using a randomized complete block design, with freeze-thaw event as a fixed effect and genetic sire-line as a block. Cooking loss and WBSF evaluations were analyzed using a split-plot design. The number of freeze-thaw events was the whole-plot factor, and end-point cooking temperature was the sub-plot factor. Genetic sire-line was considered as a random effect. Data were analyzed using PROC GLIMMIX in SAS.

Results: Pork that underwent either 1 or 2 freeze-thaw events (FT1 and FT2) demonstrated greater ($P < 0.05$) purge loss compared with CON counterparts. FT1 and FT2 pork samples exhibited similar ($P > 0.05$) levels of purge loss. A significant interaction ($P < 0.05$) between freeze-thaw treatments and end-point cooking temperature was observed for both cooking loss and WBSF. FT2 pork chops cooked to an end-point cooking temperature of 71°C demonstrated the greatest ($P < 0.05$) cooking loss, whereas CON pork chops cooked to an end-point cooking temperature of 71°C demonstrated the greatest ($P < 0.05$) WBSF. Additionally, all pork chops regardless of freeze-thaw treatments cooked to an end-point temperature of 63°C exhibited the lowest ($P < 0.05$) cooking loss and WBSF.

Conclusion: Purge loss was increased following freeze-thaw events; however, 2 freeze-thaw events did not result in greater purge loss when compared with just one freeze-thaw event. Ultimately, lowering end-point cooking temperature plays a greater role for improving pork tenderness and cooking loss than freeze-thaw events.

Keywords: cooking loss, end-point cooking temperature, freeze-thaw cycle, pork quality, tenderness

## 36 INFLUENCE OF TEMPERATURE DURING TRANSPORT ON PRODUCT YIELD AND QUALITY OF BEEF

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Objectives: This study aimed to determine the impact of temperature during transport on purge loss, color, and tenderness of beef striploin and sirloin subprimals and steaks.

Materials and Methods: Cases of beef striploins ($n = 24$) and sirloins ($n = 24$) were chosen from a commercial packing facility. Cases were equally divided between 2 pallets and loaded onto 2 refrigerated trucks. Temperature data loggers were used to validate temperature during the 2 transport periods (FT = first transport; ST = second transport). Trucks for FT were prechilled to −2.2°C (L) or 3.3°C (H), loaded, and driven 12 h to simulate transportation of subprimal products from a harvest plant to a case ready plant. At the completion of the FT period, pallets were placed in a holding cooler with a temperature of ∼1.4°C until product reached 9 d postfabrication to simulate aging requirements at a case ready plant. A subsample of each product was collected by removing one piece from the middle of each case for further analysis. Purge loss was calculated for each subsampled piece, and four 2.54-cm steaks were fabricated from each subprimal. Steaks were assigned to an ST and aging day group (day 0 or 5 of case life). Similar to the FT, one pallet was placed in 1 of 2 prechilled refrigerated trucks (−2.2°C [LST] or 3.3°C [HST]), which were driven 12 h to simulate transport from a case ready plant to a distribution center. Upon completion of the ST, the pallets were placed into a holding cooler with a temperature of ∼1.4°C for 10 d. Steaks were evaluated for color ($L^*$, $a^*$, $b^*$), purge loss and Warner-Bratzler shear force (WBSF). Color was evaluated from day 0 to day 5 to determine case life. Measurements were recorded at 2 locations on each steak and averaged daily.

Results: Subprimal purge loss was greater for HFT sirloins compared with LFT ($P < 0.05$); however, transport temperature did not influence ($P > 0.05$) purge loss of striploins. Purge loss of HFT strip steaks and sirloin steaks was increased ($P < 0.05$) compared with LFT steaks. $L^*$ and $b^*$ values of LFT strip steaks were increased ($P < 0.001$) compared with HFT steaks, but $a^*$ was not influenced ($P > 0.05$) by FT temperature. $L^*$ values of HFT sirloin steaks were increased ($P < 0.05$) compared with LFT steaks, but FT temperature did not influence $b^*$ of sirloin steaks. An FT by day interaction was observed for $a^*$ of sirloin steaks

($P < 0.01$); LFT steaks were more red on day 0 compared with HFT steaks on day 0 ($P < 0.01$). An aging day by FT temperature interaction was observed for strip steak WBSF ($P < 0.05$). Shear force of LFT strip steaks aged for 5 d was tougher than HFT steaks ($P < 0.05$). Both LFT and HFT strip steaks aged for 0 d did not differ from 5 d steaks ($P > 0.05$). An ST by day interaction was observed ($P < 0.05$) for strip steak purge loss. Strip steaks from day 0 HST had less purge loss compared with all other steaks ($P < 0.05$). Second transport temperature did not influence ($P > 0.05$) $L^*$, $a^*$, or $b^*$ values or WBSF of strip steaks or sirloin steaks.

Conclusion: These data suggest a differential response of subprimals to temperature during transport and also indicate first transport temperature has a greater impact on measures of meat quality. Thus, a universal recommendation for all meat products could not be made, and further investigation into the impacts of transportation temperatures on various meat products is vital to optimize quality and yield within the meat supply chain.

Funding Source: Funded in part by The Beef Checkoff Salaries and research support provided by state and federal funds appropriated to South Dakota State University.

Keywords: beef, color, temperature, tenderness, transportation

## 37 EFFECT OF FINISHING SYSTEM ON CARCASS CHARACTERISTICS, PROXIMATE COMPOSITION, AND FATTY ACID PROFILE OF BISON BULLS

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Objectives: This study evaluated the influence of grain- and grass-finishing systems on carcass characteristics of bison bulls and proximate and fatty acid compositions of bison steaks.

Materials and Methods: Bison bulls were initially allowed to graze native range in North-Central Nebraska until approximately 26 mo of age, when they were randomly assigned to either grain-finishing ($n = 98$; in an open lot with ad libitum access to prairie hay, alfalfa hay, and corn for 95 d prior to slaughter) or grass-finishing ($n = 98$, on pasture until slaughter). Bulls were slaughtered at approximately 29 mo of age. Hot carcass weight; ribeye area; backfat thickness; kidney, pelvic, and heart fat percentage; marbling score; and instrumental color ($L^*$, $a^*$, and $b^*$) of the exposed ribeye area at the 12th rib break and the subcutaneous fat of the carcass surface opposite the ribeye were recorded. Skeletal maturity, lean maturity, and fat color were also subjectively scored based on the ossification percentage of the thoracic buttons, lean color of the exposed ribeye, and external fat color, respectively. Strip loins were collected from a subsample of carcasses ($n = 30$ carcasses closest to the treatment average hot carcass weight) for compositional analyses. Ultimate pH was recorded, and strip loins were cut into 2.5-cm steaks. One steak was designated for fatty acid and cholesterol analysis and another steak was used for determining proximate composition. Carcass characteristics, objective color, pH, fatty acid, cholesterol, and proximate data were analyzed for the fixed effect of finishing treatment, with slaughter date as random effect in the MIXED procedure of SAS. Subjective fat color, lean maturity, and skeletal maturity scores were analyzed using the GLIMMIX procedure of SAS.

Results: Grain-finished bulls had greater ($P < 0.0001$) live and hot carcass weights; dressing percentage; ribeye area; backfat thickness; kidney, pelvic, and heart fat; and marbling scores compared with grass-finished bulls. The $a^*$ and $b^*$ values of the ribeye and $a^*$ value of backfat opposite the ribeye were greater ($P < 0.0001$) but the $L^*$ and $b^*$ values of backfat were less ($P < 0.0001$) for grain-finished bulls. A greater proportion ($P < 0.001$) of grain-finished carcasses had moderately bright red lean color, whereas a greater proportion ($P < 0.0001$) of grass-finished carcasses had moderately yellow fat color. Finishing system did not influence ($P > 0.05$) ultimate pH of bison striploins. Steaks from grain-finished bulls had an increased percentage of ($P < 0.001$) crude protein, fat, and ash content but less moisture than grass-finished bulls. Steaks from grain-finished bulls had more ($P < 0.001$) cholesterol, palmitic, stearic, oleic, linoleic, and arachidonic acids in addition to more total fatty acids (mg/g of wet tissue). However, when normalized by total fatty acids, grass-finished steaks had a greater ($P < 0.0001$) proportion of polyunsaturated fatty acids.

Conclusion: These data indicated that finishing system influences the characteristics of bison bull carcasses as well as the nutrient profile of bison meat with potentially meaningful implications to consumer health.

Keywords: bison, carcass characteristics, fatty acid, finishing system, meat quality

## 38 EFFECTS OF EXTENDED POSTMORTEM AGING AND END-POINT COOKING TEMPERATURE ON INSTRUMENTAL TENDERNESS OF PORK LONGISSIMUS DORSI MUSCLE

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Objectives: Extending periods of postmortem aging and lowering end-point cooking temperatures have both been shown, independently, to increase eating satisfaction of fresh pork. However, there are limited data on the interactive effects of extended aging and end-point cooking temperature on sensory characteristics or even instrumental quality evaluations like instrumental tenderness. Therefore, the objective of this study was to determine the influence of extended aging and end-point cooking temperature on cooking loss and instrumental tenderness of pork *longissimus dorsi* chops.

Materials and Methods: Pork *longissimus dorsi* samples ($n = 90$) from 20 different populations of pigs (4 to 5 loins per population) were obtained from a commercial pork processing facility. Each pork loin was divided into two 8-cm-thick sections that were randomly assigned to postmortem aging (wet aging at 2°C in a vacuum-sealed package) for either 14 or 21 d. After each postmortem aging period elapsed, the muscle sections were removed from the vacuum package and each muscle section was fabricated into three 2.54-cm-thick pork chops. Following the standard quality workup on the raw samples, 3 pork chops from each of the muscle sections were randomly allotted to an internal end-point cooking temperature of either 63°C, 71°C, or 79°C using sous vide cooking techniques in a water bath before cooking loss and Warner-Bratzler shear force (WBSF) were evaluated. Cooking loss and WBSF evaluations were analyzed using a split-plot design, with aging time as a whole-plot factor and end-point cooking temperature as a subplot factor. Population of the pigs was considered as a random effect. Data were analyzed using PROC GLIMMIX in SAS. The differences among the means were performed using the least significant differences test at the 5% level. Pearson correlation coefficients were determined using PROC CORR of SAS.

Results: An interaction effect ($P < 0.01$) between aging time and end-point cooking temperature was observed for cooking loss. Pork chops aged for 21 d and cooked to the end-point temperature of 79°C demonstrated the greatest ($P < 0.01$) cooking loss, whereas those aged for 14 or 21 d and cooked to 63°C exhibited the lowest ($P < 0.01$) level of cooking loss. There was no interaction ($P > 0.05$) between aging time and end-point cooking temperature for WBSF. However, WBSF increased ($P < 0.01$) as end-point temperature was increased from 63°C to 79°C. Greater WBSF was moderately correlated with an increase in cooking loss ($r = 0.40$; $P < 0.01$).

Conclusion: Although extended aging from 14 to 21 d influences fresh pork quality attributes, it did not improve pork tenderness in this study. Overall, end-point cooking temperature plays a greater role in pork tenderness than extending aging periods beyond 14 d. Pork chops cooked to 63°C regardless of aging days exhibited greater tenderness and lowest level of cooking loss.

Keywords: end-point cooking temperature, pork quality, postmortem aging, tenderness

## 39 EFFECT OF MUSCLE ON SURFACE COLOR AND BIOCHEMICAL TRAITS OF FRESH PORK DURING SIMULATED RETAIL DISPLAY

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Objectives: Differences in color stability among muscles have received limited attention in pork. The objectives of this study were to determine differences in color and biochemical characteristics among the *longissimus dorsi* (LD), *triceps brachii* (TB), and *psoas major* (PM) muscles of pork during simulated retail display.

Materials and Methods: The LD, TB, and PM were collected from 20 pigs slaughtered under university conditions and aged for 21 d at 4°C in vacuum packages. After aging, 3 chops were cut from each muscle (LD and TB, 2.54 cm; PM, 5.08 cm) and randomly assigned to 1, 3, and 5 d of retail display. Chops from a muscle within a pig were overwrapped together on 27.3 × 14.9 cm polystyrene trays and displayed under constant lighting for up to 5 d. Visual discoloration was evaluated daily by 8 trained panelists using a 10-cm line scale anchored at 0%, 50%, and 100% discoloration. Samples were considered "unacceptable" when the average visual discoloration score of a package was ≥ 20%. A Hunter spectrophotometer (31.8 mm aperture, D65 illuminant) was used daily to collect CIE $L^*$, $a^*$, and $b^*$, chroma, hue angle, 630/580 nm ratio, and proportions of myoglobin (Mb) redox forms (oxymyoglobin [OMb], deoxymyoglobin [DMb], and metmyoglobin [MMb]) on each chop in a package. One chop was removed from each package at day 1, 3, and 5 of display for analysis of oxygen consumption (OC), MMb reducing activity (MRA), and lipid oxidation. Chops removed on day 1 were also evaluated for Mb content. Data were analyzed using the MIXED procedure of SAS as repeated measures with a model that included muscle and days of display as well as their interaction.

Results: Muscles discolored at different rates during display. Over the 5 d display period, chops from the TB and PM had greater changes in $a^*$, $b^*$, chroma, 630/580 nm ratio, DMb, and OMb compared with LD chops (interaction of display time × muscle $P \leq 0.01$). Therefore, TB and PM chops had greater visual discoloration on day 4 and 5 of display compared with LD chops ($P \leq 0.01$). By day 5 of display, only 5% of TB chops and 20% of PM chops were considered "acceptable" but 85% of LD chops were acceptable. Poorer color stability in the TB and PM compared with the LD may

have resulted from increased Mb and OC and decreased MRA throughout display. Myoglobin content was greatest in the TB (2.07 mg/g meat) and least in the LD (0.74 mg/g meat; $P < 0.0001$). Furthermore, chops from the TB and PM had increased OC compared with the LD on all measurement days ($P < 0.0001$). Oxygen consumption of the LD decreased from day 1 to 3 ($P < 0.01$) but did not change over time for the TB or PM ($P \geq 0.10$). Changes in MRA over time did not differ among muscles ($P > 0.11$), but MRA was greatest in the LD on all individual display days ($P < 0.01$). Lipid oxidation increased for all muscles from day 1 to 5 ($P < 0.0001$) but did not differ among muscles on any given day ($P < 0.39$) and likely did not impact color stability differences.

Conclusion: Chops from the TB and PM were less color stable during a 5 d display period compared with LD chops but had few color stability differences from each other. Furthermore, by day 5 of display, the majority of TB and PM chops were considered visually unacceptable whereas nearly all of the LD chops were still considered acceptable.

Keywords: color, discoloration, muscle, pork, pork color

## 40 EFFECTS OF THE INCLUSION OF DRY-AGED BEEF TRIMMING AS A VALUE-ADDED QUALITY ENHANCER FOR GROUND BEEF

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Objectives: Dry aging is a traditional aging process known to naturally enhance the flavor of meat products. Although the process greatly improves the palatability, higher product loss is often reported due to the moisture evaporation. This leads to excessive trimmings to remove dehydrated surfaces, lean and fat from the products at the end of aging. Although often considered as a waste, these trimmings could potentially exert unique dry aging properties and thus could be utilized as novel meat ingredients to enhance flavor. The objective of this study was to determine the efficacy of dry-aged beef trimmings as a novel meat ingredient addition to ground beef.

Materials and Methods: Paired beef loins, *m. longissimus lumborum*, from 13 beef carcasses were collected at 5 d postmortem, split into 4 sections, and randomly assigned to 4 different aging methods: wet aging (WA), dry aging (DA), dry aging in a water permeable bag (DWA) and UV-light dry aging (UDA). All samples were aged for 28 d at 2°C, 70% relative humidity, and 0.8 m/s airflow. At the end of aging, dehydrated surfaces, lean and fat portions were trimmed from all samples. Both lean and fat trims were then collected for further inclusion into ground beef. A total of 3 independent ground beef batches consisting of 6 treatments were made. The control (CON; fresh beef and fat) and DAFAT (fresh beef and DA fat) were formulated with 80:20 lean-to-fat ratio. The WA, DA, DWA, and UDA treatments were formulated with 50% fresh lean, 30% treated lean trim, and 20% treated fat. Beef round (*m. semimembranosus*) was utilized for the fresh ground beef. All products were individually ground using a meat grinder equipped with a 8-mm plate and were reground following the formulation to generate a consistent mix. Six patties were then collected from each treatment for texture, pH, water-holding capacity (WHC), lipid oxidation, color display, and trained sensory analyses. The data were analyzed using the PROC GLIMMIX procedure from SAS with significance defined at $P < 0.05$.

Results: The addition of the trimmings only affected the chewiness of the patties, with CON having higher chewiness compared with DWA ($P < 0.05$) but was not different from the other treatments ($P > 0.05$). The hardness, adhesiveness, resilience, cohesion, springiness, and gumminess were not affected with trimmings inclusion ($P > 0.05$). The CON patties had a significantly lower pH compared with all treatments except DAFAT ($P > 0.05$). No adverse impact on the WHC was observed ($P > 0.05$). The lipid oxidation (TBARS) was not influenced by the different treatments ($P > 0.05$). However, a significant period effect was observed across all treatments, showing greater oxidation at the end of display. Color analysis indicated similar color stability for all treatments ($P > 0.05$) except for DWA, in which the treatment had lower redness and higher hue angle value at the end of display ($P < 0.05$). Trained sensory panel found that inclusion of trimming from DA and UDA reduced the perceived bloody flavor from the beef patties compared with all other treatments ($P < 0.05$).

Conclusion: The results of this study showed that the addition of dry-aged beef trimmings to fresh ground beef could potentially improve ground beef palatability without any significant adverse impact on the quality. Further studies to identify the violate and flavor precursor presence in the samples are currently in process.

Funding Source: This project was supported by Agriculture and Food Research Initiative Grant 2017-67017-26475 from the USDA National Institute of Food and Agriculture.

Keywords: beef patties, beef trim, dry-aged fat, dry aging, sensory attributes

## 41 COMPARISON OF THE VOLATILE FLAVOR PROFILE OF GROUND BEEF AND PLANT-BASED MEAT ALTERNATIVES

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Objectives: The objective of this study was to evaluate the chemical flavor profile 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), 85/15 ground beef (85/15), and 97/3 ground beef (97/3) were collected from local and national chain grocery stores in 6 different cities representing the east (University Park, Pennsylvania, and Athens, Georgia), central (West Lafayette, Indiana, and Lubbock, Texas), and west (Fresno, California, and Reno, Nevada) regions of the United States. In each city, 6 packages of each product type were purchased from at least 2 stores. One hundred and fifty grams of product were weighed out and formed into a patty using a patty press. Patties were vacuum packaged and frozen at −20°C until subsequent analyses. Prior to cooking, patties were thawed for 24 h at 0°C to 4°C. Patties were cooked on an enamel-lined cast-iron heated to 200°C ± 10°C. Patties were cooked to an internal temperature of 71°C being flipped at 35°C. Samples were immediately snap frozen in liquid nitrogen and homogenized. Volatile compounds were extracted using solid phase microextraction and then injected into a gas chromatograph coupled with a mass spectrometer. Volatile compounds were quantitated to ng/g. Data were analyzed as randomized block design with collection city serving as the block. Significance was determined at $P < 0.05$. Principal component analysis (PCA) and cluster analysis were used to further elucidate differences in volatile profile.

Results: Of the 84 compounds identified, 41 differed due to product type ($P < 0.05$). GEN patties produced the greatest concentration of hydrocarbons, esters, and carboxylic acids compared with other PBMA and ground beef ($P < 0.05$). The 2-propanone and 3-methyl-thiophene concentration was the greatest in IMP patties compared with all other products ($P < 0.05$). Both 97/3 and 85/15 GB had greater concentrations of acetoin than all PBMA ($P < 0.05$). All PBMA produced greater concentrations of pyrazines compared with the ground beef ($P < 0.05$). IMP patties had similar concentrations of 2-methylbutanal, 3-methylbutanal, and phenylacetaldehyde compared with ground beef ($P > 0.05$). GEN and BEY produced the greatest amounts of furfural, furfuryl alcohol, and 5-methylfurfural ($P < 0.05$). Cluster analysis showed BEY and GEN clustered together and separate from IMP, 85/15, and 97/3. This is echoed in the PCA, which accounted for 68.2% of the variation in the model. Factor 1 (40.25%) separated GEN and BEY from IMP, 85/15, and 97/3. However, 85/15 and 97/3 GB separated from IMP across Factor 2 (27.95%). Both ground beef products were associated with methyl hexanoate, 2,3-butanedione, acetoin, methanethiol, and 1-octen-3-ol. IMP was associated with 2-propanone, phenylacetaldehyde, 3-methyl-thiophene, and 1-octanol. GEN was associated with pyrazines, diallyl sulfide, furfuryl sulfide, 2-methyl-3-furanthiol, and triacetin. BEY was associated with decanal, heptanal, octanal, nonanal, nonane, and ethylbenzene.

Conclusion: These data indicate the volatile profile of ground beef is different from PBMA. Of the PBMA, IMP was the most similar to ground beef in regard to Strecker aldehydes. BEY and GEN plant-based products produced very different volatile profiles (pyrazines, furans) compared with both lean levels of ground beef.

Funding Source: Beef Checkoff contracted by the National Cattlemen's Beef Association.

Keywords: beef, flavor, gas chromatography–mass spectrometry, plant-based, volatiles

## 42 CHARACTERIZING SENSORY ATTRIBUTES ON VARIOUS BEEF MUSCLES UTILIZING THE F94L MYOSTATIN GENE IN BEEF-ON-DAIRY BREEDING SYSTEMS

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Objectives: There has been a recent increase in the mating of beef sires to dairy cows in the United States. The myostatin gene is a negative regulator of growth; mutations of this gene reverse its negative effect and may cause an extreme proliferation of muscle growth. There is an interest in identifying quality and composition traits of beef-on-dairy cattle that possess the F94L substitution gene. The objective of this study is to characterize the sensory quality attributes on various beef muscles carriers of the F94L gene evaluated by a trained sensory panel.

Materials and Methods: Steers resulting from the mating of 2 Limousin/Angus sires heterozygous for the F94L myostatin gene to Jersey/Holstein dams were harvested. DNA analyses were performed to identify 56 steers that possessed one or zero copies of the F94L allele. Four different beef muscles (*longissimus lumborum*, *psoas major*, *semitendinosus*, and *gluteus medius*) were fabricated into steaks ($N = 232$) 10 d postmortem and frozen until analysis. Frozen steaks were thawed for 48 h at 2°C to a range of 0°C to 4°C prior to cooking. Steaks were sorted into panels so that only one muscle and equal representation of the F94L allele was eaten per panel. Steaks were cooked at 204°C with 0% relative humidity and default fan speed in a combi-oven on a grill grate until reaching a peak internal temperature of 69°C. The steaks were then removed from the oven and rested for 2 min to allow the internal temperature to rise to 71°C. Trained panelists quantified the following attributes: beef

flavor identity, browned, buttery, fat-like, overall juiciness, liver, metallic, oxidized, roasted, sour, overall tenderness, and umami.

Results: No interactions existed between muscle and presence of the F94L substitution ($P > 0.05$). Across all muscles, steaks with the F94L substitution gene were less fat-like and juicy and had decreased umami flavor intensity than the beef muscles not containing the gene ($P \leq 0.01$). However, tenderness was not affected by the presence of the F94L substitution gene ($P > 0.05$). Sensibly, panelists identified differences in all sensory attributes among muscles ($P \leq 0.02$). Generally, the LD and PM were rated juicier and more tender as well as more intense for positively associated attributes such as beefy, browned, roasted, and fat-like and were rated less intense for off-flavors such as liver-like, oxidized, and sour than GM and SM.

Conclusion: These results indicate that various muscles obtained from cattle positive for the F94L substitution gene have an overall perceived difference in umami, juiciness, and fat-like attributes. The myostatin gene mutation, F94L gene, is a negative promoter of adipogenesis and may relate to the reduction in fat-like flavor identified by the panelists.

Funding Source: Funded by the Beef Checkoff.

Keywords: beef, dairy, F94L gene, myostatin, sensory evaluation

## 43 SEPARATION OF PORK LOINS AND CHOPS USING RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY (REIMS) EFFECT ON QUALITY AND SENSORY ATTRIBUTES

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Objectives: Previous studies have shown the ability of rapid evaporative ionization mass spectrometry (REIMS) to classify samples based on metabolomic profiling. The objective of this study was to explore REIMS as a real-time, minimally invasive tool to separate pork chops into groups based on quality attributes.

Materials and Methods: Pork chops were fabricated from loins collected from Duroc-sired barrows and gilts ($N = 82$). Corresponding live weight, hot carcass weight, and loin yield were measured. Chops were analyzed for color, marbling, and sensory attributes as well as various other objective indicators of quality and yield (pH, instrumental color, discoloration, purge loss, cook loss, and shear force). Additionally, chops were analyzed by REIMS following 3 d retail display. Canonical correlations of these quality attributes and REIMS mass bins were used to create a model, and scores derived from the correlations were used to categorize samples into "Higher," "Average," and "Lower" quality groups. These groups were then analyzed using an analysis of variance (ANOVA) to determine differences based on quality attributes.

Results: Although carcasses in each of the groups were not different in any evaluated yield measurements ($P \geq 0.43$), loins from the Higher group exhibited darker lean and a greater amount of marbling ($P < 0.01$). Chops from the Higher group had darker lean and less discoloration during retail display ($P < 0.01$). Chops from the Higher group were also rated among the most tender by panelists ($P = 0.03$) and had the numerically lowest objective tenderness. Furthermore, the Higher group exhibited the greatest pH ($P < 0.01$) as well as least purge loss and among the least cook loss ($P \leq 0.05$). The Average and Lower quality groups were not different from each other in any of these attributes, although the Lower group generally reported less favorable numerical values in a given attribute.

Conclusion: REIMS was able to separate higher quality pork loins and chops while creating a group that coincided the most favorable sensory and quality attributes. This is evidence of the ability of REIMS to create and separate groups based on quality using metabolomic profiles.

Funding Source: National Pork Board.

Keywords: mass spectrometry, metabolomics, pork, quality, rapid evaporative ionization mass spectrometry

## 44 FLAVOR PROFILE OF BEEF STEAKS OF CATTLE RAISED UNDER DIFFERENT FEEDING SYSTEMS

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Objectives: Cattle feeding systems can greatly impact sensory attributes, like flavor of meat products. Negative changes to flavor may result in rejection from consumers. Therefore, research is needed to determine the impact of different feeding systems on the flavor profile of beef. The objective of this study was to characterize the flavor profile of beef steaks from animals raised on conventional grain fed (CON; $n = 12$), 20 mo grass-fed (20GF; $n = 12$), 25 mo grass-fed (25GF; $n = 12$), and 20 mo grass-fed 45-d grain-finished (45GR; $n = 9$) feeding systems.

Materials and Methods: Trained sensory analysis was conducted at the USDA-ARS US Meat Animal Research

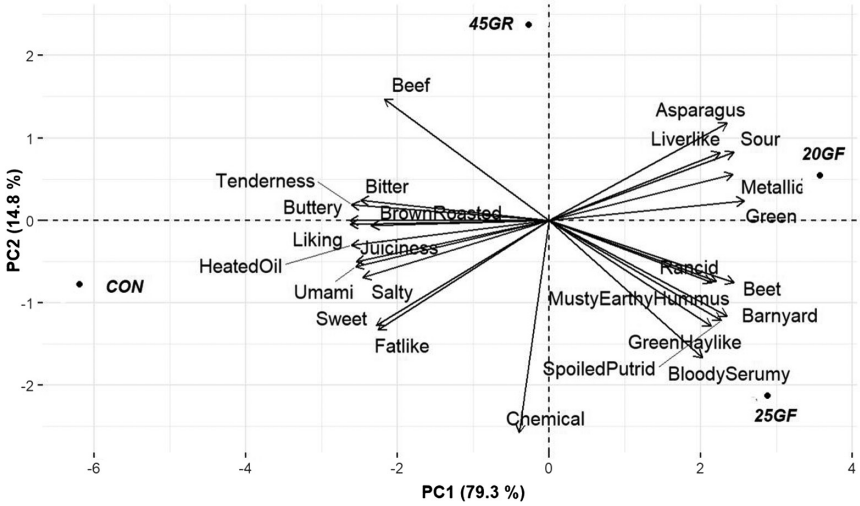


**Figure 1.** Principal component analysis (PCA) relating the flavor profile of beef obtained from different grain and grass-feeding systems. Treatments groups: Conventional grain fed (CON), 20 month grass-fed + 45 day grain finished (45GR), 20 month grass-fed (20GF), 25 month grass-fed (25GF).

Center (Clay Center, Nebraska). Steaks were thawed for 24 h at 5°C and then cooked using a conveyorized belt grill. Internal temperature was measured at the geometric center using a thermocouple thermometer. Immediately after cooking, exterior fat and connective tissue was removed and steaks were sectioned into 1.27 cm × 1.27 cm cubes. Samples were mixed, randomly selected for each panelist, and served. Because there was no delay between cooking and serving, all panelists evaluated samples in the same order. A descriptive attribute panel of experienced panelists ($n = 6$) were recruited and trained. Panelists rated overall tenderness and juiciness using an 8-point scale. (1 = extremely tough or dry; 8 = extremely tender or juicy). Panelists also evaluated flavor attributes of beef flavor identity, brown/roasted, bloody/serumy, fat-like, metallic, liver-like, green-hay-like, umami, sweet, sour, salty, bitter, barnyard, rancid, heated oil, chemical, green, asparagus, beet, buttery, spoiled/putrid, and musty/earthy/hummus on a 15-point scale (0 = not detectable; 15 = extremely strong). A total of 5 evaluation panels were conducted, 1 per day, and sample order was randomized within each session. Statistical analysis was done using R 4.1.2. Alpha level was defined as 0.05. Principal component analysis was conducted to analyze the relationship between feeding system and sensory flavor attributes using the FactoMineR package.

Results: Principal component analysis was used to visualize the relationship between diet and flavor profile, with principal component 1 and principal component 2 accounting for 79.3% and 14.8% variability, respectively (figure 1). There were significant ($P < 0.05$) differences in the flavor profiles of beef derived from cattle fed under different grass-fed systems. Panelists indicated that positive attributes like tenderness, fat-like, umami, sweet, salty, and buttery were more ($P < 0.05$) prevalent in beef from the CON and 45GR groups. Conversely, panelists associated negative attributes such as rancid, musty/earthy/hummus, spoiled/putrid, green-hay-like, barnyard, and green with beef from the 20GF and 25GF groups. However, little difference ($P > 0.05$) was noted among treatments in attributes like juiciness, brown roasted, bloody/serumy, liver-like, heated oil, chemical, asparagus, and beet.

Conclusion: Feeding system significantly impacted the flavor profile of steaks from animals. Increased grazing period did not appear to significantly improve the flavor of the grass-fed steaks. However, a short duration of grain supplementation, like that seen in the 45GR group, may help to improve the flavor of the final product for United States consumers. Therefore, additional studies are needed to assess consumer satisfaction with beef from different feeding systems.

Funding Source: This study was supported by the USDA-NIFA Hatch/Multistate Project W4177-CA-D-ASC-2553-RR: Enhancing the Competitiveness and Value of US Beef.

Keywords: beef quality, feeding system, flavor profile, grass-fed, trained sensory panel

## 45 EFFECTS OF A SINGLE DOSE IMPLANT STRATEGY ON CARCASS WEIGHT, CARCASS CHARACTERISTICS, AND MEAT QUALITY ATTRIBUTES OF ANGUS STEERS

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Objectives: In feedlots, cattle are usually implanted twice during the finishing phase, which may vary from 120 to 180 d depending on animal initial weight. In this study, we tested the effects of a short-term single dose implant strategy on hot carcass weight, carcass characteristics, and meat quality attributes of cross Angus steers.

Materials and Methods: Twelve-month-old Angus steers weighing approximately 477.54 ± 5.51 kg were randomly assigned to 1 of 2 treatments (Revalor XS implant $n = 8$ and nonimplant $n = 8$ animals). Steers were individually fed a diet containing 39.96% alfalfa and 40.24% corn. After 100 d, animals were implanted and were transported and slaughtered at a commercial processing plant. Approximately 24 h postmortem, the yield grade, ribeye area, and marbling score of carcasses were obtained directly from the plant's electronic instrument grade augmentation system. Strip loins were then fabricated and transferred to the University of Nevada, Reno, meat quality laboratory. After 7 d of aging, strip loin steaks were fabricated and assigned to the following analysis: proximate analysis (moisture and fat content), instrumental color (CIE $L^*$, $a^*$, and $b^*$), lipid oxidation (TBA, MDA/kg), cooking loss (%), and instrumental tenderness (WBSF). For proximate analysis, steaks were immediately frozen on day 7. For instrumental color and lipid oxidation, steaks were displayed at 5°C ± 2°C for 8 d under fluorescent lighting. Color was measured every day during the display period, and lipid oxidation was measured on day 0 and 7. Steaks used to estimate cooking loss and WBSF were vacuum packaged and aged for 7 d, totaling 14 d of aging. A minimum of 6 cores were sheared to determine Warner-Bratzler shear force (WBSF). Data were analyzed as a completely randomized design in which color and lipid oxidation data were evaluated as a repeated measure. Data were analyzed using the GLIMMIX procedure of SAS. The level of significance was $P \leq 0.05$.

Results: Carcasses from implanted steers had higher hot carcass weight ($P < 0.01$) and rib eye area ($P < 0.01$) when compared with carcasses from nonimplanted steers. Beef from implanted steers had higher moisture content than nonimplanted beef ($P < 0.04$). Dietary treatments did not affect marbling score, yield grade, WBSF, cooking loss, fat content, lipid oxidation, and $L^*$, $a^*$, and $b^*$ coordinates. As expected, samples displayed for 7 d had higher MDA/kg than samples from day 0 of display ($P < 0.01$).

Conclusion: A short-term single dose implant strategy allows finishers to produce heavier carcass and shorten the production cycle to improve production costs. This short-term strategy does not affect beef quality attributes.

Keywords: beef, implant, yields

## 46 THE EFFECT OF MATERNAL INFLAMMATION IN PIGS ON OFFSPRING GROWTH, CARCASS CHARACTERISTICS, AND MEAT QUALITY

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Objectives: The objective was to determine the effects of late gestational maternal inflammation in pigs on the growth, carcass characteristics, and meat quality of offspring.

Materials and Methods: Pregnant gilts were administered either lipopolysaccharide (LPS; $n = 6$) or saline (CON, $n = 6$) from day 70 to 84 of gestation. LPS gilts received an intravenous injection of reconstituted LPS every other day with the beginning dose being 10 µg/kg BW LPS and subsequent doses increasing by 12%, whereas CON gilts received a saline intravenous injection of comparable volume. Gilts farrowed naturally, and the 2 barrows and 2 gilts weighing closest to the litter average at weaning (21 d of age) were selected. Littermates were allotted to pens and remained together throughout the trial. At day 66 of age, barrows and gilts began a 3-phase feeding regimen designed to meet or exceed nutrient requirements for growing-finishing pigs. Pigs were weighed on day 0, 35, 70, and 105 of this feeding trial to determine ADG, ADFI, and G:F. On day 106, pigs were slaughtered under university conditions. Ending live weight, hot carcass weight, and dressing percentage were determined. The following day, the left side of carcasses were weighed and fabricated into primal, subprimal, and retail cuts and weighed to determine carcass cutting yields. Fresh belly characteristics and ventral loin quality were also measured. Growth data were analyzed as one-way ANOVA using the MIXED procedure of SAS with pen as the experimental unit. Carcass data were analyzed as two-way ANOVA with fixed effects of treatment and sex using pig as the experimental unit.

Results: Only minimal differences between treatments were observed for growth performance with no differences ($P \geq 0.32$) in phases 1 and 3 or overall (days 0 to 105) performance. However, in the third phase (days 71 to 105), G:F was reduced ($P = 0.03$) in CON pigs (0.30) compared with LPS pigs (0.35). Ending live weight, hot carcass weight, and carcass yield did not differ ($P \geq 0.19$) between treatments, but loin eye area was reduced ($P = 0.05$) in LPS pigs compared with CON pigs. Tenth-rib back fat did not differ ($P = 0.27$) between treatments. Moreover, estimated lean percentage was reduced ($P = 0.04$) in LPS pigs (51.94%) compared with CON pigs (52.85%). As a proportion of side weight, whole shoulder and belly weights were increased ($P \leq 0.05$) in LPS pigs compared with CON pigs; however, whole ham weight was reduced ($P = 0.04$). Ventral loin quality traits including instrumental color, subjective color, marbling, firmness, pH, and drip loss and were not different

($P \geq 0.12$) between treatments. Belly width was reduced ($P = 0.02$) by 5% (1.4 cm) in LPS pigs compared with CON pigs. However, belly flop distance was reduced ($P < 0.01$) by 34% (11.2 cm) in CON pigs compared with LPS pigs.

Conclusion: Overall, pigs born to dams experiencing late gestational inflammation had reduced loin eye area and reduced estimated lean percentage. Belly firmness was also improved in pigs from dams exposed to inflammation. These results suggest that pigs exposed to inflammation during gestation may experience a reduction in muscle deposition and increase in fat deposition.

Keywords: cutability, maternal inflammation, meat quality, muscle, pork

## 47 EVALUATION OF VARIOUS CONSUMER FREEZING METHODS OF GROUND BEEF LOAVES

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Objectives: Freezing is one of the most important preservation methods for meat and meat products because it leads to a minimal loss of quality during long-term storage. Frozen storage is used to retard undesirable biochemical reactions in meat, but there is some cell disruption and destruction of muscle fiber due to the formation of ice crystals (Sebranek, 1982). Consumers tend to buy fresh cuts and package them in inadequate packaging for freezing (Romans et al., 2001). Therefore, the objective of this study was to determine the best freezing method available to consumers purchasing ground beef loaves to maintain product quality.

Materials and Methods: Ground beef loaves formulated as an 80/20 blend ($n = 30$; 454 g/loaf) were packaged in 3 packaging types typically available to consumers: traditional PVC, Ziploc, and FoodSaver vacuum bags. After 8 mo of freezing, all loaves were allowed 24 h to thaw at 3°C. Upon opening, loaves were weighed and purge loss was calculated. Microbiological samples were taken and total plate count was determined. From each loaf, a 226 g patty was formed and cooked to an internal temperature of 71°C. Cook loss percentage was determined by weighing pre- and postcooking. Tenderness, juiciness, and rancidity were evaluated by an 8-member trained panel. Lipid oxidation was determined using the thiobarbituric acid reactive substance (TBARS) assay.

Results: Purge loss was not ($P > 0.05$) different between packaging types. However, cooking loss increased ($P < 0.05$) for the patties from loaves packaged in PVC compared with those in the Ziploc or FoodSaver vacuum bags. There was no difference ($P > 0.05$) in microbial growth between the packaging types with all levels well below spoilage. Patties from loaves packaged in FoodSaver vacuum bags were the juiciest ($P < 0.05$) followed by Ziploc and then PVC. Additionally, the patties from loaves stored in Ziploc and FoodSaver vacuum bags were more tender ($P < 0.05$) than the patties packaged in PVC. There was no difference ($P > 0.05$) in rancidity scores rated by panelists or TBARS assay among the packaging types, and all scores were well within acceptable ranges.

Conclusion: In conclusion, no variations were observed between storage types for microbiological or flavor measurements; however, the FoodSaver vacuum bags resulted in increased eating satisfaction ratings. Consumer education related to proper ground beef repackaging can assist them in maintaining product quality when freezing.

## 48 MICROBIOME ANALYSIS OF VACUUM PACKAGED RAW BEEF TREATED WITH ORGANIC ACIDS

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Objectives: The United States beef industry exported 1.2 million tons of beef in 2020 with a $7.6B economic value. A significant portion of these products are exported as vacuum-packaged "fresh, chilled beef." These products are considered premium; therefore, slowing the growth of microbial spoilers during storage and distribution is paramount to maintaining their market value. The objective of this study was to determine the impact of organic acid treatment on raw beef from 2 different processors on the spoilage microbiome during extended storage.

Materials and Methods: Meat sampling procedures and plate count data from this experiment were previously reported (RMC 2021 Abstract 59). Briefly, beef chuck rolls ($N = 24$) were cut in half and assigned to 1 of 4 treatments: 4.5% lactic acid, 2.5% Beefxide, 380 ppm peroxyacetic acid, or a no-treatment control. After treatment, samples were stored at 2.7°C for 112 d, and meat homogenates were prepared every 28 d. DNA was extracted (DNA QuickExtract Solution 1.0), amplified targeting the V4 region of the 16S rRNA gene with polymerase chain reaction (PCR), and sequenced with the Illumina MiSeq (Illumina Inc., San Diego, California). Sequences were processed and analyzed in R 4.1.2 and Mothur 1.46.1 using the DADA2 pipeline. Amplicon sequence variants were assigned to known taxa using the Silva database. Relative abundance was determined using phyloseq in R. Statistical differences in observed and Chao1 metrics were determined using the incomplete block model with treatment, location, day, and block included in the model using SAS 9.4. Bray-Curtis

dissimilarity was used to conduct a principle coordinate analysis of the first 2 components and PERMANOVA. Treatment, location, sampling day, block, and a treatment: day interaction were included in the PERMANOVA model.

Results: Organic acid treatments did not have a significant impact on alpha diversity (Chao1 $P = 0.39$, observed $P = 0.30$), but alpha diversity was significant for location Chao1 $P < 0.01$, observed $P < 0.01$). Consistent with previous observations of meat spoilage, alpha diversity also decreased during storage (Chao1 $P < 0.01$, observed $P < 0.01$). The principal coordinate analysis resulted in significant day, location, treatment, and day: treatment observations ($P < 0.01$). High diversity between samples on day 0 was observed, followed by the large clustering of many of the remaining samples during subsequent sampling, indicating that organic acid treatment did little to cause differentiation between the bacterial communities present during storage. *Lactobacillus* were predominant regardless of treatment type and were the most predominant by day 28 proportionately. *Pseudomonas* abundance was higher in control and peroxyacetic treatment groups compared with lactic acid-based treatments, suggesting that lactic acid may be effective at controlling *Pseudomonas*. Because *Pseudomonas* were not primary spoilers in these samples, the shelf life of these products was not altered in comparison with the other antimicrobial treatments.

Conclusion: Treatment with organic acids did not result in large changes in composition of the microbial communities of raw meat. Although lactic acid may be useful in controlling *Pseudomonas* growth, these treatments did little to impact the composition of communities containing lactic acid bacteria in vacuum packaged raw beef.

Funding Source: Funded in part by the Beef Checkoff and Nebraska Beef Council.

Keywords: bacterial spoilage, chilled beef, organic acids

## 49 CHANGE IN MYOGLOBIN DENATURATION AMONG THREE DEGREES OF DONENESS AND THREE MUSCLES

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Objectives: Although the raw color field is heavily researched, cooked color has been less studied within whole muscles. Therefore, the objective of this study was to determine the changes in myoglobin denaturation through cooking 3 different muscles to medium rare, medium, or well-done degrees of doneness.

Materials and Methods: Beef strip loins ($n = 12$) and top butts ($n = 12$) were collected at a Midwest beef processing plant and brought to Kansas State University for processing. The strip loins (LL) were denuded and the top butts were denuded and separated into the *biceps femoris* (BF) and *gluteus medius* (GM). The muscles were sliced into 2.5-cm steaks and assigned to one of the following treatments: raw, medium rare (MR), medium (MED), or well done (WD). All 3 muscles were aged for 28 d at 4°C and then frozen and held at −20°C. The steaks assigned for lab assays were cooked to the appropriate degree of doneness (DOD) to peak temperatures of 62.8°C, 71°C, or 76.7°C for each DOD. $L^*$, $a^*$, $b^*$ color readings were taken using a HunterLab Miniscan, and then samples were powdered immediately for moisture, fat, and myoglobin denaturation. Myoglobin denaturation was determined using a modified protocol provided in the AMSA color guidelines. The samples were weighed, homogenized in a potassium phosphate buffer, centrifuged, and filtered. A 200 µL sample was plated on a 96-well plate in duplicate and 1% sodium hydrosulfite was added to reduce all forms of myoglobin to deoxymyoglobin. The plates were evaluated with a spectrophotometer at 433 nm and the absorbance was used to calculate the myoglobin denaturation (%) of each sample. Data were analyzed using SAS PROC GLIMMIX with a split-plot design with the muscle as the whole plot and the DOD as the subplot factor. A $P < 0.05$ was considered significant.

Results: Cook loss increased ($P < 0.05$) with each DOD, whereas the LL had the lowest ($P < 0.05$) cook loss compared with the other muscles. Similarly, moisture content decreased ($P < 0.05$) with each DOD, whereas the LL resulted in the lowest ($P < 0.05$) moisture content. The $L^*$ values were not impacted ($P > 0.05$) by the different DOD; however, the LL resulted in the highest ($P < 0.05$) $L^*$ value followed by the GM and then the BF. As expected, the $a^*$ values decreased ($P < 0.05$) with each different DOD. The MR and MED treatments had a higher ($P < 0.05$) $b^*$ value in comparison with the WD treatments. Similar to the $a^*$ values, the myoglobin denaturation increased ($P < 0.05$) for each DOD, but muscle did not have ($P > 0.05$) an impact. Myoglobin was denatured 29.08%, 48.34%, or 70.17%, respectively, at each DOD.

Conclusion: Myoglobin is a complicated molecule that has been shown to undergo post-translational changes in previous research, but the question of how much of myoglobin is denatured at certain DOD was not answered until this research. As expected, the myoglobin denaturation percentage increased with increasing DOD and behaved similarly to changes in the $a^*$ values. These changes were accompanied by expected changes in $L^*$, $a^*$, $b^*$, moisture content, and cook loss. This research gives more insight to the impacts of cooking and the changes that proteins, especially myoglobin, undergo between different DOD.

Keywords: cooked color, degree of doneness, denaturation, myoglobin, proteins

## 50 DETERMINING THE EFFECTIVENESS OF ROSEMARY EXTRACT ON THE SHELF LIFE 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 shelf life of ground beef patties under different retail display conditions.

Materials and Methods: Ground beef patties were produced from an 85%/15% blend purchased from a local grocery retailer, finely ground through a 0.953 cm plate, and separated into 151.2 g patties ($n = 64$). Patties were randomly assigned into a control group (no antioxidants added) or a rosemary extract antioxidant group. The patties were individually packaged using polyvinyl chloride overwrap. Each patty was randomly assigned into 1 of 2 lighting intensity groups (3,000 K vs. 3,500 K). The ground beef was then subjugated to a simulated retail display for 5 d under continuous light emitting diode (LED) lighting and rotated once a day within a multideck display case each day. Following each day of retail display, a patty was removed from each treatment and immediately vacuum packaged and frozen at −20°C. Thiobarbituric acid reactive substances analysis (TBARS) was conducted to evaluate lipid oxidation of the ground beef patties. Each sample was then thawed for 10 to 12 h to 5°C, placed in liquid nitrogen, and powdered using a Nutribullet blender. Ten grams of sample was weighed into a 50 mL conical tube, and TBARS was analyzed through the modified procedure of Buege and Aust (1978) as described by Luque et al. (2011). A standard curve for the assay was run for each day of testing. Samples were blended with 30 mL deionized water and then centrifuged. Two milliliters of the supernatant was removed and added to a 50 mL centrifuge tube in which the trichloroacetic acid reagent and butylated hydroxyanisole were added. Samples were heated, cooled, and centrifuged. Two 1 mL samples were added to a 48 well plate and then analyzed. Data were analyzed as a split-plot design, in which batch served as the whole plot and lighting served as the subplot.

Results: There was no significant three-way interaction between display day, antioxidant, and light temperature and no interaction between display day × light temperature and antioxidant × lighting temperature ($P \geq 0.539$). No effect of lighting temperature was observed ($P > 0.05$). There was an interaction observed between antioxidant × day ($P < 0.0001$). Overall, a higher magnitude of difference was expressed through each progressive day of display, expressing a linear response of lipid oxidation in the control group, whereas the treated antioxidant group remained relatively consistent. Additionally, a main effect of antioxidant type ($P < 0.05$) and display day ($P < 0.05$) were observed. Each replicated antioxidant treatment expressed lower lipid oxidation than the control, regardless of lighting intensity ($P < 0.05$). Furthermore, a reduction in display day yielded a net reduction in lipid oxidation, regardless of lighting temperature or antioxidant supplementation ($P < 0.05$).

Conclusion: These results indicate that adding an antioxidant to ground beef does decrease lipid oxidation when compared with ground beef that has not been treated with antioxidants. These data also suggest that antioxidants reduce lipid oxidation regardless of light temperature. As retailers opt for more bright white lights, antioxidants can still be used to successfully extend product shelf life and potentially improve color stability, even in ground product.

Funding Source: This study was funded by the University of Arkansas Dale Bumpers College of Agricultural Sciences and Natural Resources Undergraduate Research and Creative Project Grant.

Keywords: antioxidant, ground beef, lighting, oxidation, retail display

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

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Objectives: Extended freezing time decreases the color of meat products. However, limited studies have evaluated the effects of packaging type and extended frozen storage periods on the color and lipid oxidation of ground beef patties. The objective of this study was to evaluate the effects of packaging type and frozen storage time on color and lipid oxidation of ground beef patties.

Materials and Methods: Beef shoulder clods ($n = 6$) were procured from a commercial meat processing facility. Shoulder clods were coarse ground first and then finely ground to make 150 g patties using a handheld patty former. The patties were randomly assigned to 4 packaging conditions (polyvinyl chloride overwrap [PVC], vacuum, high-oxygen modified atmospheric packaging [HiOx-MAP], and carbon monoxide-MAP [CO-MAP]). The CO-MAP gas flush consisted of 0.4% oxygen, 30% carbon monoxide, and 69.6% nitrogen, whereas the HiOx-MAP gas flush consisted of 80% oxygen and 20% carbon dioxide. Prior to freezing, HiOx-MAP and CO-MAP patties were stored at 21°C for 24 h to facilitate oxymyoglobin and carboxymyoglobin formation, respectively. The patties were frozen in the dark at −21°C for 3 d, 3 mo., and 6 mo. $L^*$, $a^*$, and $b^*$ values of frozen patties were recorded during storage using a

HunterLab MiniScan spectrophotometer. Lipid oxidation was determined as thiobarbituric acid reactive substances (TBARS) values. The data were analyzed using the PROC GLM procedure of SAS.

Results: A freezing period × packaging interaction ($P < 0.0001$) resulted for $L^*$, $a^*$, $b^*$, and lipid oxidation. CO-MAP packaged patties had greater redness ($P < 0.0001$) than vacuum, PVC, and HiOx-MAP with increased storage time. HiOx-MAP and CO-MAP packaged patties demonstrated a decrease ($P < 0.0001$) in $L^*$ values with increased storage, whereas PVC packaged patties had increased ($P < 0.0001$) $L^*$ values. There were no differences ($P > 0.05$) in $L^*$ values for patties in vacuum package during storage. Lipid oxidation increased ($P < 0.0001$) with frozen storage time across packaging types. By 6 mo of frozen storage, CO-MAP packaged patties had the least ($P < 0.0001$) lipid oxidation compared with PVC < vacuum < HiOx-MAP packaged patties.

Conclusion: These results showed that CO-MAP packaging conditions could reduce ground beef color deterioration during an extended frozen storage period without affecting lipid oxidation.

Keywords: freezing, ground beef, lipid oxidation, meat color, packaging

## 52 EFFECTS OF LAMB COVER CROP GRAZING SYSTEMS ON MEAT QUALITY AND COMPOSITION

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Objectives: Limited research has been conducted investigating the effects of lamb cover crop grazing systems on meat quality and composition. Therefore, we examined the impact of 4 rearing systems on the shear force, composition, and eating quality of lamb.

Materials and Methods: Four finishing strategies were used: brassica backgrounded and grain-finished (BKG; 4 wk background + 4 wk grain), finished on a cover crop mixture (MIX), finished on brassica cover crop (BRO), and grain-finished control (GRN). Data were collected from 120 Dorset × Polypay lambs over 2 y (60 lambs/y) blocked on initial weight and then assigned at random to treatment (3 replicates of 5 lambs/treatment). All finishing strategies were designed to ensure maximum intake for dry matter. Because of variation in growth rate, treatments were slaughtered at different times: 6 wk for GRN; 8 wk for MIX, BRO, and BKG. Loins were obtained from each carcass, aged to 7 d postmortem, and portioned into 2.54-cm-thick chops for shear force, composition, and eating quality (year 2 only). All analyses utilized the *longissimus* muscle only. Warner-Bratzler shear force (WBSF) and sensory samples were cooked on a clam shell 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). Untrained consumer sensory panelists ($n = 105$) evaluated halved loin chops representing each treatment for overall liking, flavor liking, tenderness, and juiciness on 100-point line scales and indicated overall acceptability. Statistical analysis was conducted using PROC GLIMMIX of SAS with treatment as the fixed effect for all variables. Year was included as a random effect for shear force and compositional data. Panelist was included as a random effect for sensory data.

Results: Fat and moisture percentages were similar ($P > 0.05$) among treatments. Protein percentage varied by treatment, where BRO and MIX had greater ($P < 0.05$) protein than GRN or BKG. Treatment did not influence WBSF values ($P > 0.05$). Likewise, consumers did not detect differences ($P > 0.05$) in tenderness or overall liking. However, consumers differentiated ($P < 0.05$) flavor liking and juiciness. Consumers liked the flavor of BRO more ($P < 0.05$) than GRN. Consumers scored BRO loin samples juicier ($P < 0.05$) than all other treatments. Consumer acceptability was similar ($P > 0.05$) among treatments. Correlation analysis revealed flavor liking was most strongly tied to overall liking ($r = 0.79$; $P < 0.01$), followed by tenderness ($r = 0.68$) and juiciness ($r = 0.61$).

Conclusion: Limited differences were observed in the meat quality and composition of lamb loin chops following various cover crop finishing systems. Only protein percentage varied among treatments. Shear force values were similar, as were sensory tenderness scores. Despite flavor liking and juiciness differences, typically in favor of the BRO treatment, overall liking and acceptability were similar among all treatments. These results suggest cover crops can be used in lamb finishing systems without sacrificing product quality or altering loin composition.

Keywords: composition, cover crop, lamb, quality

## 53 THE INFLUENCE OF FREEZING DURATION AND PACKAGING TYPE ON TRAINED PANEL RATINGS OF BEEF STEAKS

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Objectives: The objective of this study was to evaluate the sensory traits of beef steaks from 2 packaging types and 2 muscles from fresh steaks and 2 freezing storage durations.

Materials and Methods: Paired beef strip loins (USDA IMPS #180) and top sirloin butts (USDA IMPS #184) were collected from USDA Choice carcasses ($n = 20$) and cut into 2.54-cm-thick steaks represented by the *longissimus lumborum* (LL) and the *gluteus medius* (GM). The steaks were individually vacuum packaged and transported from Canyon, Texas, to Fayetteville, Arkansas. Once delivered, the steaks were packaged in the randomly assigned treatment: vacuum packaging (VAC) or overwrap packaging (OW). The steaks were placed in a simulated retail display under continuous light emitting diode (LED) lighting for 3 d. Steaks were separated by assigned storage treatment, fresh, 1 wk frozen, and 1 mo frozen, and placed in frozen storage at −20°C, with the exception of the fresh treatment, which was immediately analyzed after retail display. After the storage duration was completed, the steaks were transported back to Canyon, Texas, for trained sensory panels conducted within a 3-d period. Prior to panels, 8 panelists were selected after training for a 5-d period. Before serving the sample steaks, the panelists received anchors using the methods of Adhikari (2011). During each panel, 4 steaks (VAC LL, VAC GM, OW LL, and OW GM) were cooked to a medium degree of doneness (71°C) using clamshell grills and cut into a steak thickness × 1 × 1 $cm^3$ cube. Panelists were served one sample from each treatment in random order. Electronic surveys were used by panelists to evaluate each sample for beef flavor identity, brown/roasted, bloody/serumy, fat-like, umami, overall tenderness, overall juiciness, and off-flavors including liver-like, fishy, oxidized, cardboard, rancid, refrigerator/stale, bitter, and sour. Each trait was rated on a 100 mm line scale on an electronic tablet. Statistical analyses were conducted using the procedures of SAS (9.3; SAS Institute Inc., Cary, NC). Treatment comparisons were tested for significance with $\alpha = 0.05$.

Results: No interactions were observed for beef flavor identity, brown/roasted, bloody/serumy, fat-like, overall tenderness, or overall juiciness ($P > 0.113$). Additionally, freezing duration did not impact beef flavor identity, brown/roasted, fat-like, overall tenderness, or overall juiciness ($P > 0.05$). Beef flavor identity did not differ due to packaging type or muscle ($P > 0.05$). The OW samples were higher than VAC samples for brown/roasted ($P < 0.05$). Packaging type and duration affected samples rated as bloody/serumy ($P < 0.05$). The VAC steaks were higher for bloody/serumy than the OW steaks ($P < 0.05$). Bloody/serumy decreased with each freezing duration: fresh >1 wk frozen and >1 mo frozen ($P < 0.05$). Expectedly, fat-like was greater in LL samples compared with the GM samples ($P < 0.05$). Moreover, muscle type and packaging type affected overall tenderness ($P < 0.05$). As expected, LL samples were more tender than GM samples ($P < 0.05$), and VAC steaks were more tender than OW steaks ($P < 0.05$). Similar to overall tenderness, the LL samples were higher in overall juiciness than GM samples, and VAC samples were juicier than OW samples ($P < 0.05$).

Conclusion: In conclusion, freezing duration had no impact on palatability, but VAC steaks and LL were more tender and juicier than OW steaks and GM.

Funding Source: This study was funded by the National Cattlemen's Beef Association.

Keywords: beef, flavor, sensory

## 54 EVALUATION OF BOS TAURUS × BOS INDICUS CROSSES, IMPLANT PROTOCOL, AND STRATEGIC SUPPLEMENTATION ON EATING QUALITY OF GRASS-FED BULL MEAT

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Objectives: This study hypothesized the tropical adaptability of sires used for the crossbreeding program as well as if the use of supplemental feeding and implant protocol may affect eating quality of bull meat. The experiment aimed to assess the independent effects of sire breed [tropically adapted (TROP) vs. temperate (TEMP)] and its interactions with supplementation [mineral (MS) or strategic protein-energy supplementation (SS)] and implant protocol [repeated (day 0 and day 90) Zeranol-72 mg implantation (ZER-ZER) or Trenbolone Acetate-140 mg/Estradiol-20 mg (day 0) followed by Zeranol-72 mg (day 90) (TBA/E2-ZER)] on meat quality traits of pasture-finished young bulls.

Materials and Methods: Ninety-nine yearling bulls representing 3 breed types of *Bos indicus* (*BI*) influence [TROP purebred *BI* ($n = 24$); TROP *B. taurus* crossbred (F1 Senepol or Romosinuano × *BI*) and ¾ Romosinuano ($n = 42$) and TEMP *B. taurus* crossbred (F1Angus or Simmental × *BI*) ($n = 33$)] were randomly selected and allotted to supplementation (SUPPL) and implant protocol (IMPL) treatments to be compared in Warner-Bratzler shear force (WBSF) and trained panel sensory ratings at a desirable conformation end-point with a suitable market weight of 480 kg. A linear mixed model was applied to a completely randomized design with a 3 × 2 × 2 factorial arrangement that included, as fixed effects, breed type (BT), SUPPL, IMPL, and the first-order interactions for meat quality traits.

Results: Nonsignificant BT × IMPL interactions ($P \geq 0.05$) were observed for sensory ratings. BT × SUPPL and

BT × IMPL interactions were observed for WBSF ($P < 0.01$). BT did not differ ($P > 0.05$) in WBSF within the MS group, whereas in the SS group, the TEMP *B. taurus* crossbreds exhibited lower WBSF values (4.72 kg) than the TROP *BI* (6.29 kg; $P < 0.001$) and TROP crossbreds (5.57 kg; $P = 0.03$). The BT × IMPL interaction showed that the WBSF of steaks from TROP BI implanted with ZER-ZER was greater than their counterparts implanted with TBA/E2-ZER (6.82 vs. 5.28 kg; $P = 0.0001$). Within the TBA/E2-ZER implanted group, the 3 BT did not vary in WBSF. Contrarily within the ZER-ZER group the WBSF values were different among the BT (TROP purebreds *BI* > TROP *B. taurus* crossbreds > TEMP *B. taurus* crossbreds; $P < 0.05$). The interaction SUPPL × IMPL ($P = 0.02$) for WBSF, muscle fiber tenderness, overall tenderness ($P = 0.02$), and amount of connective tissue ($P < 0.01$) was observed. Within the MS group, the WBSF for ZER-ZER steaks was greater than the TBA/E2-ZER counterparts (6.23 vs. 5.60 kg; $P < 0.04$). SS offered bulls implanted with the TBA/E2-ZER produced steaks that were rated as more tender and with a lesser amount of connective tissue than bulls offered SS and implanted with ZER-ZER and MS counterparts ($P < 0.05$).

Conclusion: Additional nutrient supplementation elicits a positive response in textural quality (lower shear force values) from the temperate *B. taurus* crossbreds as compared with the tropically adapted breed types. Animals that received strategic supplementation combined with an aggressive implant strategy increased tenderness of loin steaks. The improvements in eating quality attributes observed herein with the combination of treatments were modest and may as a result be insufficient to please local consumers.

Funding Source: Institute of Agronomic Research and the Council for the Scientific Development of the Universidad del Zulia.

Keywords: bull, crossbreeding, eating quality, grass-fed, implant regimes

## 55 COLOR AND PH COMPARISONS FOR 9 DIFFERENT MUSCLES IN THE PORK CARCASS

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Objectives: Even though the loin primal is used as the standard for quality assessment, it is well recognized among meat scientists that muscles throughout the carcass differ in their quality attributes. The purpose of this study was to evaluate color and pH for 9 different muscles in the pork carcass.

Materials and Methods: Over a 9-mo period, a total of 350 pork carcasses (173 barrows and 177 gilts) were selected at a commercial pork plant. One side from each carcass was transported in meat combos to the Univ. of Guelph Meat Laboratory (approximately 24 to 28 h postmortem). Upon arrival, pork carcasses were fabricated according to NAMP specifications. Immediately following fabrication, the boneless loin, the boneless shoulder, and the boneless ham were collected for evaluation purposes. One 2.5-cm-thick chop from the 10th rib location of the *longissimus dorsi* was collected, whereas the *triceps brachii* and *serratus ventralis* muscles were identified in the boneless shoulder primals, and the *biceps femoris*, *semitendinosus*, *semimembranosus*, *adductor*, *rectus femoris*, and *vastus lateralis* muscles were identified in the boneless ham primals. Each muscle was faced and allowed to bloom for 30 min prior to objective evaluation of color and pH. Instrumental color (Minolta CR-400, CIE $L^*a^*b^*$ color scale, illuminant $D_{65}$, 2° observer, and 8-mm aperture) and pH (Hanna HI 98161) were measured on at least 3 different locations for each muscle and were averaged before data analysis occurred. Data were initially analyzed using PROC GLIMMIX of SAS as a randomized complete block design with fixed effects of muscle, sex, and their interaction. Slaughter date was used as a random effect, and hot carcass weight was used as a covariate. Least-squares means were separated using the PDIFF option of SAS with a Tukey-Kramer adjustment. Data for the different muscles were analyzed using PROC CORR of SAS, and Spearman rank correlation coefficients were generated.

Results: Pork used in this study was considered "normal" in pH range based on loin measurements (mean = 5.59; min. = 5.40; max. = 5.94). No significant interactions between muscle and sex were reported ($P \geq 0.20$) for instrumental color ($L^*$ and $a^*$) and pH. Significant main effects ($P \leq 0.01$) for muscle and sex existed for instrumental lightness ($L^*$), instrumental redness ($a^*$), and pH. The *longissimus dorsi* had the lightest and least red color and lowest pH compared with the other 8 muscles (mean differences ranged from 0.98 to 8.70 for $L^*$, 3.98 to 12.56 for $a^*$, and 0.026 to 0.409 for pH). Muscles from barrows were slightly lighter (0.33 greater for $L^*$), slightly less red (0.14 less for $a^*$), and slightly higher for pH (0.036 greater) than respective values for gilts. $L^*$, $a^*$, and pH were weakly to moderately correlated between the *longissimus dorsi* and the other 8 muscles. Spearman rank correlation coefficients (r) ranges ranged from 0.27 to 0.46 for $L^*$, 0.24 to 0.57 for $a^*$, and 0.15 to 0.45 for pH.

Conclusion: This research suggests that *longissimus* muscle pH and color values are not good predictors of pH and color for other pork carcass muscles. There were only weak to moderate correlations among *longissimus* muscle instrumental color and pH values and values for the respective traits for other muscles in the pork carcass. To fully

address color and pH of a pork carcass, consideration should be given to the individual muscles that are of interest.

Funding Source: Funding for this project was provided by Ontario Pork (Grant #18-003) and the Natural Sciences and Engineering Research Council of Canada.

Keywords: pork color, pork muscle myology, pork pH, pork quality

## 56 UNDERSTANDING MUSCLE-SPECIFIC DISCOLORATION AND MICROBIAL SPOILAGE OF BEEF STEAKS USING 16S RRNA SEQUENCING

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Objectives: Different beef muscle cuts from the same carcass can discolor at different rates. For example, *psoas major* (PM) typically discolors (browns) by 2 d of retail display, whereas *longissimus lumborum* (LL) remains cherry-red for 6 d. Previous research has indicated PM reaches microbial spoilage faster, which may suggest that microbes play a role in the differential color stability of beef. Culture-dependent methods are routinely used to assess microbial quality of meat products, but they only capture a small percentage of microbes present. Microbiome analysis using 16S ribosomal RNA (rRNA) gene sequencing provides a powerful way to capture these unculturable organisms. Therefore, the objective of this study was to characterize the microbial composition of beef LL and PM during retail display using 16S rRNA sequencing.

Materials and Methods: Paired USDA Select beef LL and PM ($N = 10$; $n = 5$) were collected and aged for 14 d at 2°C. After aging, muscles were fabricated into 2.54-cm steaks and overwrapped with polyvinyl chloride (PVC) film on foam trays. Steaks were retail displayed (3°C) with continuous fluorescent lighting for 7 d. On each display day, lightness ($L^*$), redness ($a^*$), and yellowness ($b^*$) were measured, and trained visual panelists determined lean color and percentage discoloration. Then, half of each steak ($n = 10$) was used for measuring pH, water activity, and metmyoglobin reducing activity (MRA), and the other half was used for traditional bacteria enumeration methods (aerobic plate counts [APC], lactic acid bacteria counts [LAB], and *Pseudomonas* spp. counts [PSEUDO]) and 16S rRNA analysis. Bacterial DNA sequences were processed with the QIIME2 pipeline to provide a relative abundance feature table with taxonomy and phylogenetic tree. Alpha and beta diversity and relative abundance were analyzed in R. All other parameters were analyzed in R using ANOVA, and Tukey's test was used to determine significance at $\alpha = 0.05$.

Results: The redness ($a^*$ value) of PM steaks was lower ($P < 0.05$) than that of LL steaks from 2 d of display. Additionally, panelists indicated PM steaks had greater ($P < 0.05$) percentage discoloration from 2 d. The pH of PM was greater ($P < 0.05$) than LL until 5 d, whereas the water activity was similar ($P > 0.05$) for both muscles for all days. MRA was lower ($P < 0.05$) in PM compared with LL on all days. Initial (0 d), APC, LAB, and PSEUDO counts were similar ($P > 0.05$); however, after 24 h of display, PM had greater ($P < 0.05$) microbial growth for both APC and LAB. The PSEUDO counts were greater ($P < 0.05$) in PM from 2 d of display. The microbiome analysis indicated that Faith's PD (alpha diversity) was different ($P < 0.05$) between muscles across all days. However, the alpha or beta diversity between muscles on the same day was similar ($P > 0.05$). Similarly, relative abundance of taxa at the phylum level was similar ($P > 0.05$) between muscles on the same day.

Conclusion: The results showed that PM discolors faster and had more microbial growth in the first 2 d than LL during retail display. However, no major differences were observed in the microbiome between PM and LL, suggesting that the microbiome difference alone may not be responsible for rapid discoloration of the PM muscle in beef. Therefore, further studies examining the intrinsic biochemical differences and its interaction with the microbiome is required to understand the muscle-specific discoloration of beef muscles.

Keywords: beef, color stability, meat color, microbiome, spoilage

## 57 EFFECT OF DIETARY FIBER ON CARCASS CHARACTERISTICS, LOIN QUALITY, AND BELLY QUALITY IN GROWING-FINISHING PIGS SELECTED FOR LOW OR HIGH FEED EFFICIENCY

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Objectives: The objective was to investigate the effect of dietary fiber on carcass characteristics, belly quality, and loin quality in growing-finishing pigs selected for low or high feed efficiency.

Materials and Methods: Eighteen Landrace × Large White sows with high and low estimated breeding value on feed conversion ratio (EBV-FCR) were inseminated with semen from Large White with known EBV-FCR as well. Thus, sows and boars will match for insemination based on EBV-FCR (high-high, low-low) to generate 9 litters of low feed efficiency pigs and 9 litters of high feed efficiency pigs. A total of 94 growing barrows and gilts (56 days of age [DOA] and average body weight of 27.44 ± 0.33 kg) representing each efficient group were assigned to low fiber (LFD; corn-soybean meal-based diet) or high fiber (HFD; wheat-canola meal-based diet) contents in a 2 × 2 factorial arrangement of treatments with 12 replicates of 1 to 2 pigs per replicate. Animals were sent to harvest in 2 groups (representing all treatments in each harvest day) when reaching final weight of 111.73 ± 5.82 kg and with average days on feed of 70 (average 126 DOA) and 77 (average 133 DOA), respectively. At 24 h postmortem, chilled left carcass sides were evaluated for backfat depth and thickness (on first rib, last rib, and last lumbar), muscle color, and marbling scores. Boneless loins and skin-on boneless bellies were obtained from the left side carcasses and transported in coolers at 4°C. At 48 h postmortem, loin pork chops (2.5 cm thick) were obtained for drip loss (at 24 and 48 h), pH, and objective color evaluation. Belly dimension (length, width, and thickness) and belly firmness (subjective belly firmness score and belly flop angle) were measured.

Results: There was an interaction between dietary fiber and feed efficiency group on marbling score ($P = 0.01$), where high-efficient (HFE) pigs fed with HFD presented the lowest marbling scores on pork chop surface. Regardless of dietary fiber, HFE animals presented a thinner back fat on the last lumbar ($P = 0.02$) and reduced backfat depth ($P = 0.04$) compared with low-efficient animals (LFE). No other differences in carcass traits were detected between efficiency groups ($P > 0.05$). Regardless of efficiency group, pork chops from animals fed with LFD presented more drip loss (at 24 and 48 h; $P < 0.05$) and higher $b^*$ (yellow; $P = 0.02$) and chroma (vividness; $P = 0.04$) values. On belly quality, LFE pigs showed a thicker belly than HFE pigs ($P = 0.01$). Also, animals fed with LFD presented bellies with a thicker and wider flop distance than those fed with HFD ($P < 0.02$).

Conclusion: Crossbred offspring pigs from diverse efficiency parents express minimal changes in carcass traits and pork quality; however, LFE pigs can present higher fatness levels. Furthermore, feeding crossbred offspring with LFD, even though it can present certain water loss, can improve pork color and belly firmness.

Keywords: carcass characteristics, feed efficiency, fiber, growing-finishing pigs, meat quality

## 58 THE IMPACT OF FEEDING HEMP BYPRODUCT ON CARCASS CHARACTERISTICS

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Objectives: Hempseed cake, a hemp byproduct, could potentially be an alternative protein and fiber source for ruminants such as cattle due to cattle's digestive efficiency. However, cannabinoids (including cannabidiol [CBD] and (-)-$\Delta^9$-tetrahydrocannabinaol [THC]) found in hemp are of concern due to physiologic effects when ingested. CBD is known for anti-inflammatory activity, and THC for psychotropic activity. Yet, hemp with significantly less than 0.3% THC (dry matter basis) remains an alluring feed alternative with precedence in animal rations predating the delegitimization of industrial cannabis in the early 20th century.

The objective of this study was to evaluate the impact of inclusion of hempseed cake in a late finishing ration on the carcass characteristics of commercial heifers.

Materials and Methods: Crossbred heifers ($N = 32$) were randomly assigned to 1 of 2 treatments (CON or HEMP) and to 1 of 4 withdrawal dates (day 0, 1, 4, or 8) corresponding to treatment withdrawal prior to harvest. The CON treatment consisted of corn silage, corn grain, and dried distillers grain with solubles (DDGS), and the HEMP treatment replaced DDGS with hempseed cake. Carcass data included live weight (LW), hot carcass weight (HCW), dressing percentage (DP), USDA yield grade (YG), and quality grade (QG). PROC MIXED procedure from SAS 9.4 was used to determine treatment differences across fixed effects (treatment group and withdrawal time) for LW, HCW, DP, YG, and QG.

Results: No differences were observed across treatment or withdrawal days for LW ($P = 0.81$), HCW ($P = 0.77$), DP ($P = 0.91$), YG ($P = 0.40$), and QG ($P = 0.41$). The similarities in carcass characteristics between the CON and HEMP carcasses should be noted.

Conclusion: Inclusion of hempseed cake in the finishing ration of commercial heifers did not affect carcass characteristics in either a positive or negative manner.

Funding Source: The project was partially supported by a coordinated agreement between NDSU and the USDA Agricultural Research Service.

Keywords: carcass, crossbred heifers, dried distillers grain with solubles, hempseed cake, industrial hemp

**Table 1.** Interactions of withdrawal days and treatment groups for harvest characteristics of crossbred beef heifers between CON and HEMP diets

| | | Withdrawal Days | | Trt × Withdrawal Day Interaction *P* Value | | | |
|---|---|---|---|---|---|---|---|
| Carcass Data | Trt* | 0 | Trt *P* Value | 1 | 4 | 8 | |
| **Live Weight (kg)** | CON | 716 ± 28.92 | 687 ± 28.92 | 685 ± 28.92 | 692 ± 28.92 | 0.42 | 0.81 |
| | HEMP | 665 ± 28.92 | 673 ± 28.92 | 686 ± 28.92 | 689 ± 28.92 | | |
| **Hot Carcass Weight (kg)** | CON | 432 ± 18.45 | 408 ± 18.45 | 421 ± 18.45 | 418 ± 18.45 | 0.47 | 0.77 |
| | HEMP | 399 ± 18.45 | 400 ± 18.45 | 420 ± 18.45 | 420 ± 18.45 | | |
| **Dressing Percentage (%)** | CON | 60 ± 0.69 | 59 ± 0.69 | 61 ± 0.69 | 60 ± 0.69 | 0.94 | 0.91 |
| | HEMP | 60 ± 0.69 | 59 ± 0.69 | 61 ± 0.69 | 60 ± 0.69 | | |
| **USDA Yield Grade** | CON | 3.4 ± 0.32 | 3.15 ± 0.32 | 3.45 ± 0.32 | 3.63 ± 0.32 | 0.87 | 0.40 |
| | HEMP | 3.5 ± 0.37 | 3.0 ± 0.37 | 3.95 ± 0.32 | 3.03 ± 0.32 | | |
| **USDA Quality Grade†** | CON | 2.0 ± 0.09 | 2.0 ± 0.09 | 2.0 ± 0.09 | 2.0 ± 0.09 | 0.33 | 0.41 |
| | HEMP | 1.75 ± 0.09 | 2.0 ± 0.09 | 2.0 ± 0.09 | 2.0 ± 0.09 | | |

*Trt represents treatment; Control (CON) = 20% corn silage, 55% corn grain, 20% DDGS; HEMP = CON diet with replacement of 20% DDGS with 20% hempseed cake.

†USDA Quality Grade; Prime = 1.0–1.99, Choice = 2.0–2.99.

## *59 COOKING METHOD INFLUENCES ON SURFACE COLOR OF NITRITE-EMBEDDED PACKAGED DARK-CUTTING STEAKS*

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Objectives: Packaging dark-cutting steaks in nitrite-embedded film improves redness by forming bright red nitric oxide myoglobin. However, when steaks containing nitric oxide myoglobin are cooked, they present a redder external color as the pigment is heat stable. Limited knowledge is available on the effects of cooking method on external color. The objective of this study was to determine the effect of cooking method on dark-cutting steaks packaged in nitrite-embedded film.

Materials and Methods: Six dark-cutting beef strip loins (pH = 6.04) at 5 d postmortem were collected from Creekstone Farms (Arkansas City, Kansas). Steaks were sliced 1.91 cm thick and randomly selected to be packaged in vacuum packaging or nitrite-embedded film. Steaks were held in dark storage for 7 d to form bright red nitric oxide myoglobin, and instrumental color was evaluated daily using a HunterLab MiniScan spectrophotometer. Following the storage period, steaks were cooked to 71°C using a randomly selected cooking method of either a flat-top grill, impingement oven, Rational oven, or George Foreman grill. External cooked color was evaluated using a HunterLab MiniScan spectrophotometer with 3 separate readings taken across the surface of the steak. Cooked steaks were butterflied to expose the cooked interior and evaluate internal color using a HunterLab spectrophotometer. Percent cook loss was evaluated by weighing steaks before and immediately after cooking. The data were analyzed using the GLIMMIX Procedure of SAS ($n = 6$ replications) and considered significant at $P < 0.05$.

Results: There is a significant packaging × retail day effect on raw color. Raw steaks packaged in nitrite-embedded film had greater $a^*$ values ($P < 0.05$) than steaks in vacuum package. There is a significant packaging × cook method effect on cook loss and external color. The nitrite-embedded film and vacuum-packaged steaks were not different ($P > 0.05$) in cook loss for each respective cooking method. The Rational oven had greater ($P < 0.05$) cook loss than the George Foreman grill and flat-top grill. Steaks in nitrite-embedded film had greater ($P < 0.05$) external surface $a^*$ values for all cooking methods compared with the vacuum-packaged steaks. Nitrite-embedded film steaks cooked in the impingement oven had greater ($P < 0.05$) external surface $a^*$ values than steaks cooked in the George Foreman grill and Rational oven. There were no significant differences in external $a^*$ values between nitrite-embedded film steaks cooked in the impingement oven and flat-top grill. There is a cook method effect ($P < 0.05$) on internal cooked color. The flat-top grill reported significantly greater internal $a^*$ values than the other 3 cooking methods. There was no significant difference in cooked interior $a^*$ values between nitrite-embedded film and vacuum-packaged steaks.

Conclusion: The results indicate the cooking method influences the external cooked color of dark-cutting steaks when packaged in nitrite-embedded film. Thus, selecting an appropriate cooking method can minimize persistent pinking in cooked meat products. Redder external color may negatively impact consumer perception because these steaks appear atypical to their normally packaged counterparts.

Keywords: cooked meat color, dark-cutting beef, nitrite-embedded film

## 60 THE EFFECT OF HOT CARCASS WEIGHT AND CARCASS LOCATION ON POSTMORTEM TEMPERATURE AND PORK LOIN QUALITY

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Objectives: The aim of this study was to determine the effects of hot carcass weight (HCW) and carcass location on postmortem muscle temperature and its relationship with pork loin quality traits.

Materials and Methods: Carcasses ($n = 71$) were categorized based on HCW: light (99 to 109 kg), medium (116 to 126 kg), and heavy (134 to 144 kg). Data loggers (Thermochron iButton Device, model DS1921G, Maxim Integrated) were placed in the right sides of pork carcasses at approximately 45 min postmortem. For each carcass, data loggers were placed in the shoulder (*latissimus dorsi*), loin (*longissimus dorsi*), and ham (*semimembranosus*). Temperature was recorded from 1 h until 22 h postmortem. After data loggers were removed, left sides were fabricated at 22 h postmortem to yield boneless loins. Loin quality was evaluated on the ventral face of the loin near the 10th rib including drip loss, pH, and instrumental color (Minolta CR-400 Chroma Meter colorimeter, 2° observer, 8 mm closed aperture, and D65 illuminant calibrated). Two loin chops (2.54 cm thick) were vacuum packaged and aged for 14 d at 4°C, then stored frozen for Warner-Bratzler shear force (WBSF) analysis. Chops were cooked to 63°C and 71°C. Temperature data were analyzed as a two-way ANOVA using the MIXED procedure of SAS with the fixed effects of HCW category and carcass location. Pearson correlation coefficients between loin quality traits and loin temperatures were determined using the CORR procedure of SAS. Loin quality and shear force data were also analyzed as a one-way ANOVA using the MIXED procedure of SAS with the fixed effect of HCW category.

Results: From 3 h until 22 h postmortem, ham temperature was greater than ($P < 0.0001$) shoulder temperature, which was greater than ($P < 0.0003$) loin temperature. Similarly, from 9 h until 22 h postmortem, temperatures of heavy carcasses were greater than ($P < 0.05$) medium and light carcasses. From 14 h to 22 h postmortem, temperatures of medium carcasses were greater than light carcasses. There were no interactions between HCW category and carcass location ($P = 0.08$). Drip loss was not correlated with temperature from 8 h to 17 h ($P \geq 0.06$) and at 22 h ($P = 0.12$). Drip loss was weakly correlated with temperature at 18 h to 21 h ($r = -0.26$ to $-0.29$). However, HCW categories did not differ in drip loss ($P = 0.25$). Ultimate loin pH was not correlated with temperature from 8 to 18 h ($P \geq 0.11$) but was weakly correlated with temperatures from 19 to 22 h ($r = 0.23$ to 0.31). However, HCW categories only tended to differ ($P = 0.08$) in ultimate loin pH with light (5.52), medium (5.52), and heavy (5.57). Instrumental $L^*$, $a^*$, and $b^*$ were not correlated ($P \geq 0.09$) with temperature decline at any time point, and HCW categories did not differ in instrumental color ($P \geq 0.91$). Similarly, WBSF values at 63°C ($P \geq 0.65$) and 71°C ($P \geq 0.60$) were not correlated to temperature decline from 8 h to 22 h, and there were no differences for WBSF between HCW categories at 63°C ($P = 0.33$) or 71°C ($P = 0.40$).

Conclusion: In all HCW categories, hams chilled the slowest and loins chilled the fastest, with shoulders falling intermediate. Furthermore, heavier carcasses chilled more slowly than lighter carcasses. However, under university chilling conditions in this study, postmortem loin temperature differences between HCW categories did not result in changes in loin quality or cooked meat tenderness.

Keywords: heavy weight pigs, meat quality, pork, temperature decline

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## 61 EVALUATION OF GROWTH, MEAT QUALITY, AND SENSORY CHARACTERISTICS OF WOOL, HAIR, AND COMPOSITE LAMBS

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Objectives: Lamb consumption has plateaued at 1 lb per person per year, making the industry look for new opportunities, such as hair sheep possibly having a milder flavor that could increase consumer appeal. The objectives of this study were to evaluate the carcass quality, shelf life, tenderness, and sensory characteristics of wool, hair, and composite (wool × hair) lamb carcasses.

Materials and Methods: Twenty-five lambs [Wool (Suffolk × Polypay/Targhee; $N = 8$), Hair (Dorper × Dorper; $N = 9$), and Composite (Dorper × Polypay/Targhee; $N = 8$)] were harvested under USDA inspection at the University of Idaho Meat Lab. Hot carcass weights were recorded. At 48 h postmortem, back fat, body wall, and rib eye area were measured to calculate percent boneless closely trimmed retail cuts and yield grade. Conformation and flank streaking were evaluated to determine quality grade. Loins (IMPS 231, NAMP 2014) were fabricated from each carcass and wet-aged at 0°C until 10 d postmortem. Following aging, 2.54-cm bone-in loin chops were cut and randomly assigned to 4 d of retail display, Warner-Bratzler shear force (WBSF), or sensory

analyses. Thiobarbituric acid reactive substances (TBARS), an indicator of lipid oxidation, were analyzed on days 0 and 4 of retail display. Subjective color was evaluated daily. Objective color measurements ($L^*$, $a^*$, and $b^*$) were observed once daily using a Nix Color Sensor. Two chops from each lamb were used for WBSF analysis. Samples were cooked to an internal temperature of 71°C. After cooling, each chop had three 1.27-cm cores removed parallel to the muscle fiber. Cores were then sheared perpendicular to the muscle fiber. Three chops were used for the consumer taste panel. Chops were cooked as described and served warm to panelists, who received one sample from each breed. The consumer panel ($N = 81$ panelists) rated samples for overall acceptability, texture, juiciness, and flavor. A mixed model analysis of variance was used to assess breed differences, in which the fixed effects were treatment and lamb, with repeated measures of days. Discernable effects were considered at $P < 0.05$.

Results: Wool lambs had significantly heavier hot carcass weights ($P < 0.001$; Wool 32.34 kg, Hair 23.03 kg, Composite 24.56 kg), larger rib eye areas ($P = 0.019$), and a higher dressing percent ($P < 0.001$) than the other breeds. There were no detected differences in TBARS values between breeds ($P = 0.114$); however, lipid oxidation increased with longer retail display time across all breeds ($P < 0.001$). There was an interaction observed between breed and days of retail display for browning ($P = 0.002$); on day 1, the composite breed had more browning than the Suffolk breed. Differences in subjective marrow color were observed between breeds ($P = 0.015$) and between days ($P < 0.001$). No differences were observed between breeds for $L^*$ values ($P = 0.109$), $a^*$ values ($P = 0.485$), and $b^*$ values ($P = 0.529$). Oxygenated lean color increased between retail display days ($P < 0.001$). Overall, color deteriorated throughout all breeds over retail display days. There were not differences observed in WBSF assessment ($P = 0.209$) or in consumer acceptability ($P = 0.391$).

Conclusion: Based on results, the wool lambs had a better carcass yield with the composite lambs being more similar to the hair breed. Breed differences between wool, hair, and composite did not have sensory differences that would negatively impact consumer purchase appeal.

Funding Source: We gratefully acknowledge financial support from the National Sheep Industry Improvement Center.

Keywords: color, flavor, hair sheep, lamb, wool sheep

## 62 IMPACT OF PACKAGING AND REST TIME POSTCOOKING ON THE EXTERNAL COLOR OF BEEF LONGISSIMUS LUMBORUM STEAKS FROM NORMAL PH AND SLIGHTLY ELEVATED PH

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Objectives: Many top chefs are now recommending that consumers should rest their beef for a period following cooking before slicing and eating. However, limited studies have evaluated the color of steaks that have been rested postcooking. Therefore, the objective of this study was to evaluate the impact of resting time postcooking on the objective external color measurements of beef strip steaks from USDA Choice and slightly elevated pH strip loins subjected to 3 different packaging types.

Materials and Methods: Beef strip loins from normal pH and abnormally darker colored at slightly elevated pHs ($n =$ 6/loin type) were obtained from a commercial packing plant and aged for 14 d in vacuum package bags under refrigeration. Strip loins were cut into six 2.54-cm-thick steaks from the anterior end of each loin and were randomly assigned to 1 of 3 packaging types: carbon monoxide modified atmosphere packaging (CO-MAP; 0.4% CO, 69.4% nitrogen, and 30% carbon dioxide), high-oxygen-MAP (HiOx-MAP; 80% oxygen and 20% carbon dioxide), or vacuum package. Steaks were displayed under retail conditions for 5 d prior to cooking on a clamshell style grill (George Foreman, Salton Inc., Columbia, MO). Before cooking, steaks were removed from the retail case and set out for approximately 25 min to allow the external surface of the steak to reach room temperature. The internal steak temperature was monitored using a handheld thermometer (Thermapen MK4, Thermoworks). Steaks were removed from the grill once the internal temperature reached 65°C, and the temperature rise was monitored and recorded so that a peak internal temperature of 71°C was achieved. Steaks that were designated for no rest time immediately had the external surface color measurements taken with a HunterLab Miniscan Spectrophotometer across 3 locations on the packaging exposed side of the steak. Those steaks designated for the 7-min rest period were allowed to rest on a plastic tray at room temperature prior to the external color being measured in the same manner as those that were not rested. The 3 readings across the surface of each steak were averaged, with $L^*$, $a^*$, $b^*$, hue, and chroma values being calculated according to the AMSA Meat Color Guidelines. All data were analyzed using the GLIMMIX procedure of SAS.

Results: There were no significant 2 or 3-way interactions for $L^*$, $a^*$, $b^*$, hue, and chroma. However, the main effects were significant for color. $L^*$ values were greater ($P < 0.01$) for the steaks packaged in the HiOx-MAP than steaks packaged in CO-MAP and vacuum package, indicating a lighter external surface color. Steaks packaged in HiOx-MAP have lower ($P < 0.05$) $a^*$ and chroma values than those packaged in CO-MAP and vacuum package, indicating less surface redness in the steaks packaged in HiOx-MAP. Steaks packaged in vacuum packaging received higher ($P \leq 0.05$) hue values than steaks packaged in CO-MAP or HiOx-MAP, signifying a less intense hue.

Conclusion: Slightly elevated pH and postcooking resting period did not affect the external cooked color of steaks; however, packaging type did have a significant effect on the external cooked color.

Keywords: beef, cooked color, external color, rest time

## 63 DOES MORE INHERENTLY TENDER BEEF NEED TO BE AGED AS LONG AS IN THE PAST?

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Objectives: Hypothesis: Today's more tender beef does not need as many days of postmortem aging to be acceptably tender.

Materials and Methods: Selection of 26 upper two-thirds USDA Choice, 26 lower one-third USDA Choice, and 26 USDA Select carcasses from electrically stimulated nondairy/*Bos indicus* cattle were divided evenly across 2 collection dates. Beef ribeye rolls ($n = 74$), strip loins ($n = 77$), and top sirloin butts ($n = 78$) were obtained, vacuum packaged, and transported to a processing facility. Within 48 h of collection, eight 2.54-cm steaks were portioned from each ribeye roll and strip loin. The *M. gluteobiceps*, the *M. gluteus profundus*, and *M. gluteus accessories* were removed from the top sirloin butts. The *M. gluteus medius* was cut into five 2.54-cm-thick portions. To define aging treatments, the day of subprimal identification and packaging (pack date) at the commercial processing facility was defined as "Day 0," resulting in steaks being cut on Day 2. Therefore, steaks were assigned to 1 of 8 aging times (2, 4, 6, 8, 10, 12, 14, 21 d post-pack date). All steaks were individually identified, vacuum packaged, and stored under refrigerated conditions (~4°C; never frozen) before being cooked for Warner-Bratzler shear (WBS) force determination. Because of inclement weather that created unsafe road conditions for research personnel, steaks from the second product collection were not cooked on days 6 or 8 and are not included in the data analyses. Raw steaks were weighed, then cooked on flat-top griddles preheated to 177°C ± 3°C. Steaks were flipped when internal temperatures reached 35°C and were removed at 70°C. Final cooked weights were collected, and total cook times and yields were determined for each steak. Cooked steaks were stored (~4°C) for 12 to 18 h. Steaks ($n = 1,606$) were trimmed of visible connective tissue to expose muscle fiber orientation. Six cores (1.3-cm diameter) were obtained from the *M. longissimus thoracis et lumborum* and 3 to 6 cores were removed from *M. gluteus medius*, with subsequent Warner-Bratzler shear force testing. Data were analyzed using a mixed model function to perform an independent analysis of variance (ANOVA). Each subprimal type had aging time, quality grade, and their interaction as main effects; source, animal and anatomical steak position were included as random effects in the model. Models were reduced as appropriate, and least-squares means were separated using a Student *t* test with an alpha level of 0.05.

Results: There were no differences in mean WBS force values across USDA quality grades categories for ribeye or top butt steaks. Select and Top Choice strip loin steaks had similar shear force values, whereas Select strip loin steaks had a higher value than Choice strip loin steaks. Differences in WBS force values were identified across aging days for steaks from all 3 subprimal types. There was no significant ($P > 0.05$) improvement in objective tenderness of any steak type after day 10, irrespective of USDA quality grade/brand category.

Conclusion: Some foodservice establishments require a minimum aging of 14 d based on customer requirements or their own quality assurance programs. The last several National Beef Tenderness Surveys have found more tender beef than those initially conducted, and it may be that a minimum of 10 d of postmortem aging is sufficient to assure optimal tenderness for steaks from these USDA grade groups and subprimals.

Funding Source: Funded in part by the Beef Checkoff.

Keywords: aging, beef, tenderness, Warner-Bratzler shear force

## 64 THE EFFECT OF INCREASING CARCASS WEIGHT ON HAM WEIGHT, PROCESSING TRAITS, AND CURED COLOR

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Objectives: Hot carcass weights (HCW) of pigs are expected to further increase in coming years, but the effect of increased HCW on ham processing and quality is unknown. Therefore, the objective of this study was to determine the effects of increasing carcass size on ham processing and cured color characteristics.

Materials and Methods: Carcasses ($n = 85$) from pigs slaughtered under experimental conditions were divided into 3 HCW categories: Light (99 to 109 kg; $n = 30$), Mid (116 to 126 kg; $n = 30$), and Heavy (134 to 144 kg; $n = 25$). Right side whole hams were fabricated into an inside, outside, knuckle, inner shank, and lite butt. Inside, outside, and knuckles from an individual ham were placed together in nylon netting and weighed. The hams were multineedle injected with a Schröder Injector Marinator model N50 (Wolf-tec Inc., Kingston, NY) targeting 120% of each green weight. The cure solution targeted 1.52% salt, 0.33% sodium tripolyphosphate, 0.014% sodium nitrite, and 0.05% sodium erythorbate in the cooked ham. Pump weight was taken directly after injection. After draining for 30 min, nylon

netting was removed and ham pieces were individually macerated. The 3 pieces from an individual ham were placed into a plastic bag and then tumbled together under vacuum for 2 h. Three-piece hams were prepared for each carcass. Hams were cooked for 10 h to an internal temperature of 65.6°C and allowed to cool for 24 h. A 2.54-cm ham steak was cut, and instrumental *L**, *a**, and *b** color measures were taken on 4 visual quadrants of the ham steak and then averaged. Data were analyzed as a one-way ANOVA using the MIXED procedure in SAS with the main effect of weight class and blocked by genotype and sex. Means were considered significantly different at $P \leq 0.05$.

Results: Whole and trimmed hams and ham subprimal weights were heavier ($P < 0.01$) on an absolute basis in heavier weight classes with the exception of the lite butt that was not different ($P = 0.15$) between weight classes. In general, ham cuts from Heavy carcasses were about 20% to 25% heavier than those from Light carcasses, whereas Mid carcass cuts were 10% to 15% heavier than Light carcasses. Bone and trim weight were also increased ($P < 0.01$) in heavier weight classes. However, on a percentage of chilled side weight basis, weight of whole and trimmed ham, ham subprimals, ham bones, and ham trim were reduced ($P \leq 0.05$) in Heavy carcasses compared with Light carcasses. Given the increased weight of ham cuts, it was expected that fresh 3-piece ham weight, pump weight, drain weight, stuffed weight, and cooked weight all increased ($P \leq 0.05$) in Heavy and Mid compared with Light. Cooked yield percentage was greatest ($P < 0.01$) in Mid (90.3) compared with Light (89.1) hams ($P \leq 0.05$), with Heavy (89.8) being intermediary and similar to both Mid and Light ($P \geq 0.05$). There were no differences between weight classes in cured ham steak instrumental lightness ($P = 0.33$). Instrumental redness and yellowness decreased ($P < 0.01$) approximately 0.84 and 0.67 units, respectively, in Light hams compared with the average of Mid and Heavy hams, which were similar ($P \geq 0.05$) to each other.

Conclusion: Increasing HCW results in heavier ham primals, trimmed subprimals, fresh ham components, and cooked hams on an absolute basis but not as percentage of side weight. Increasing HCW did not have a detrimental effect on ham processing traits or cured color.

Funding Source: National Pork Board.

Keywords: color, ham, heavy pigs, hot carcass weight, processing

## 65 SHELF-LIFE ATTRIBUTES ANALYSIS IN BEEF TRIMMINGS AFTER IMMERSION IN LACTIC ACID (1% to 2%)

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Objectives: The main purpose of this study was to compare the changes in sensorial attributes such as color (visual and instrumental) and odor, through time, for ground beef with lactic acid.

Materials and Methods: Twenty-eight ground beef chubs were treated with lactic acid (1% to 2%), ground, and vacuum packaged at the beef processing plant on the same day for later transport to the Meat Laboratory at Texas Tech University to be stored at 0°C to 1°C in a dark storage facility until further process. Chubs were randomly sorted to spend different storage times (7, 14, 21, and 28 d). When the storage time was reached, visual and instrumental color was evaluated by a trained panel (7 panelists) using an 8 point descriptive scale (1 = pale purple-red; 2 = slightly pale purple-red; 3 = moderately light purple-red; 4 = purple-red; 5 = slightly dark purple-red; 6 = moderately dark purple-red; 7 = dark purple-red; 8 = extremely dark purple-red). Instrumental color was measured in triplicates using the HunterLab instrument (*L**, *a**, and *b** values were recorded). Right after the chub was open, odor was also evaluated by the panelists, who scored each sample for off-odor intensity of each odor (acidic, oxidized, sweet, metallic, spoiled) using a 5-point scale (1 = no off-odor; 2 = slight off-odor; 3 = small off-odor; 4 = moderate off-odor; 5 = extreme off-odor). After the color evaluation, chubs were regrinded and placed in 5 different polystyrene trays, wrapped with an oxygen-permeable polyvinyl chloride film, and displayed in retailer cases at 0°C to 1°C. Color and odor measurements were taken every 12 h (0 h after grinding, 30 min, 12 h, 24 h, 36 h, and 48 h), and when using the HunterLab instrument (Hunter Miniscan XE model 45/O-S, equipped with a 6 mm measurement port calibrated at an illuminant D65 and 10 degrees standard observed), 3 measurements per tray with film were assessed. Visual color for ground beef worst-point lean color was evaluated by panelists (6), for 3 retail displays days using an 8-point descriptive scale (1 = very bright red; 2 = bright red; 3 = dull red; 4 = slightly dark red; 5 = moderately dark red; 6 = dark red to reddish-tan; 7 = dark reddish-tan; 8 = tan to brown). For odor, trays were unwrapped and were smelled by the panelists and evaluated using the scale described for the odor evaluation in chubs. An ANOVA analysis was performed between storage and retail display time. All interactions were significant for each color parameter ($P < 0.001$).

Results: Chub *L** values increased as the day of storage increased (from 50.79 for day 7 to 53.46 for day 28); meanwhile, *a**, *b**, and chroma values decreased and chubs' visual color also decreased from 5.79 to 3.93 for day 7. In case of odors, off-odors as oxidized, acidic, and spoiled increased as storage days increased. For trays, higher *L** values were found for 0 and 0.5 h, and for *a**, *b**, and chroma, higher values were only found for 0 h. In general terms, *a**, *b**, chroma, and hue angle decreased as retail display times

increased. The panel detected a discoloration of ground beef trays and an increase in off-odors as the retail display increased.

Conclusion: As storage time and tray retail displays increased, the instrumental, visual color, and odor values changed negatively, presenting mainly discoloration and acidic and oxidized odors.

Keywords: color, ground beef, odor, sensory attributes

## 66 SHELF-LIFE ANALYSIS OF GROUND BEEF TREATED WITH CITRIC ACID AND OZONATED WATER

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Objectives: Show the effect of beef trimmings treated with a citric acid immersion and an ozonated water spraying over the color and odor of ground beef at different storage and retail display times.

Materials and Methods: Beef trims from multiple same day combos were treated with a citric acid solution immersion (Citrilow, Safe Foods Corp., North Little Rock, AR; 22°C to 24°C, pH 1.2, 12 s) and an ozonated water (BioSafe) spraying (1.5 to 2.3 ppm, Oxidation Reduction Potential [ORP] 700 to 900 mV, 10°C to 24°C, and pressure ≥ 20 psi). Trims were grinded and formed 28 ground beef vacuum-packaged chubs; these were assigned to the dark storage times (7, 14, 21, and 28 d). After time was reached, color was evaluated visually (trained panel = 7) and instrumentally through the film (HunterLab D65). For visual color, an 8-point purple-red scale was used (1 = pale purple-red; 3 = moderately light purple-red; 5 = slightly dark purple-red; 8 = extremely dark purple-red). Color $L^*$, $a^*$, and $b^*$ values (in triplicate) were used to calculate hue and chroma. For off-odor (acidic, oxidized, sweet, metallic, spoiled) evaluation, each panelist scored on a 5-point scale (1 = no off-odor; 3 = small off-odor; 5 = extreme off-odor). Chubs were regrinded and placed in polystyrene trays (1 lb) overwrapped with a PVC film and displayed in retail case. Odor and color were measured at the end of each retail display time (at 0, 0.5, 12, 24, 36, and 48 h). A time of 0 h was used for chubs without grinding, and 0.5 h was used for samples with full oxygenation. Instrumental color and odor panel were done following the same method and scale described for chubs. Meanwhile, visual color was evaluated by trained panelists (6) for ground beef worst-point lean using an 8-point scale (1 = very bright red; 3 = dull red; 5 = moderately dark red; 8 = tan to brown). ANOVA was run between storage period and retail display time.

Results: All interactions were significant for each color parameter ($P < 0.001$). Related to the sensory attributes for chubs, $b^*$ values at 14 d of storage were the highest (15.89). The hue angle increased at the same rate as the days of storage augmented. Moreover, $a^*$ (22.19 to 19.80) and chroma (26.35 to 24.55) values decreased as chub storage time increased. Similarly, the visual color score decreased (6.29 to 3.79), meaning that time makes chubs became more purple and paler. Following the same pattern, off-odors increased over time, with the highest values at 28 d of storage acid 2.81, oxidized 2.19, and spoiled 1.31. For trays, higher values of $L^*$ were found at 28 d and 21 d and at 0 h and 0.5 h. Chroma (45.83), $a^*$ (35.45), and $b^*$ (29.03) highest values were found at 7 d and 0 h; the lowest values were at 28 d and 48 h. Values decreased as storage and retail display times increased. Besides, hue values increased with time, with the highest value (0.92) at 28 d and 48 h. Further, visual color maximum value of red discoloration was found at maximum storage and retail display times (7.77). Likewise, off-odors increased as chub storage and retail display increased, and the highest values were found at 28 d and 48 h.

Conclusion: Both the storage and the retail display time affect shelf-life variables on treated ground beef. Instrumental color showed that $a^*$ and chroma decreased on the chubs while the storage and display retail time increased, and visual evaluation showed decrease over time on chubs and increase over time on trays. Odor values for acidic, oxidized, and spoiled off-odors increased as the storage and retail display time raised.

Keywords: BioSafe, Citrilow, color score, odor score

## 67 EFFECTS OF HIGH-PRESSURE PROCESSING ON DARK-CUTTING BEEF COLOR

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Objectives: The objective was to evaluate the effects of different high-pressure processing (HPP) levels on surface color of dark-cutting beef.

Materials and Methods: Eight USDA Choice (mean pH = 5.5; normal pH beef) and 12 dark-cutting (mean pH = 6.3) strip loins were obtained from a commercial packing plant within 1 d of harvest. Loins were cut into equal sections, vacuum packaged, and randomly assigned to HPP treatment of 0 (no HPP), 300, 450, and 600 MPa. Normal pH beef was not HPP treated and served as a control. Following 48 h of dark storage at 2°C, loin sections were cut into 1.9-cm-thick steaks, placed in Styrofoam trays

overwrapped in polyvinyl chloride (PVC) film, and placed in retail display for 8 d. The surface color readings were measured through film every 24 h using a HunterLab MiniScan spectrophotometer (Illuminant A10°) while a trained color panel ($n = 6$) evaluated discoloration, paleness, and lean color on steaks. Oxygen consumption (OC), metmyoglobin reducing activity (MRA), and lipid oxidation were evaluated on day 0, 4, and 8 of retail display. The data were analyzed using the GLIMMIX Procedure of SAS.

Results: There was a significant pressure level × day interaction resulted for all instrumental color measurements. Throughout the retail display, $L^*$ values of the higher-pressure levels (450 and 600 MPa) were greater ($P < 0.05$) than 300 MPa and controls. When panelists evaluated lean color and discoloration, there was a significant pressure level × day interaction. Steaks treated at 300 MPa exhibited brighter red color and lower thiobarbituric acid reactive substance values than other pressure levels and normal pH control steaks ($P = 0.0023$). There was no difference in redness ($a^*$) and red intensity (chroma) between HPP-treated steaks and DC control steaks.

Conclusion: The results indicate that 300 MPa can improve the redness of dark-cutting beef without affecting other quality parameters.

Keywords: dark-cutting beef, high-pressure processing, meat color, retail display

## 68 SOUS VIDE COOKERY AND HOLD TIMES COMPARED WITH CLAM SHELL COOKING ON THE IMPACT OF OBJECTIVE TENDERNESS

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Objectives: Sous vide (SV) is a highly repeatable form of cooking growing in popularity for the home consumer and restaurant industry. Because of the increased popularity and repeatability, SV may be a viable method for the objective evaluation of beef tenderness. To date, there is little information on the impact of SV cookery or timing concerning objective beef tenderness compared with clam shell methodology. The objective of this study was to evaluate the use of SV and hold times on the impact of *longissimus lumborum* (LL) objective tenderness when compared with clam shell cooking.

Materials and Methods: Sixteen frozen posterior 1/3 LL sections were selected from a total of 80 LL from a prior steer finishing study (aged 21 d) so that 8 slight and 8 small marbling score LL were selected (slight = 356 ± 10; small = 450 ± 10). Within marbling score and prior treatment block, the LL were randomly allocated to 1 of 2 steak thicknesses (Thick1 = 2.5 cm; Thick2 = 1.9 cm) and cut on a bandsaw with a cutting guide. Steaks were assigned to 1 of 5 cook treatments anterior to posterior within a loin section. The first steak was assigned to clam shell (CS), cooked, and removed at 68°C targeting 71°C end-point; steaks 2 through 5 were cooked sous vide at 72.5°C (accounting for thermocouple margin of error), with steak 2 (SV0) samples removed from the water bath upon reaching 71°C and steak 3 (SV30), 4 (SV60), and 5 (SV90) being sous vide to 71°C and then held for an additional 30, 60, and 90 min, respectively. Post-cooking, steaks were trayed, covered with plastic wrap, and placed in a cooler (4°C) for 20 to 24 h. After cooling, 6 cores (1.25 cm) were removed from each steak parallel to the muscle fiber, allowed to equilibrate to room temperature, and sheared perpendicular to the muscle fibers with a Warner-Bratzler shear blade. The peak force of the 6 cores from each steak were averaged for Warner-Bratzler shear force (WBSF). Data were analyzed as a split plot mixed model (SAS 9.4).

Results: There were no 2- or 3-way interactions for marbling score, steak thickness, or cooking method ($P > 0.05$) except a 2-way steak thickness by cook method interaction for time to reach 71°C ($P < 0.01$). All Thick1 sous vide steaks were similar and took longer to cook than Thick2 sous vide steaks, which were similar to each other. Clam shell cooked steaks were similar to each other regardless of thickness and took less time to reach 71°C than either thickness cooked sous vide. Steak thickness did not affect any other cooking traits or WBSF ($P > 0.32$). Marbling score did not affect thaw loss or WBSF ($P > 0.20$), but slight steaks had greater cook loss than small steaks (27.0% vs. 23.8% ± 0.85%; $P = 0.01$). Steaks cooked SV0 had less cook loss (19.4% ± 1.01%) than CS for all other SV methods (26.3%, 25.1%, 27.8%, and 28.6% ± 1.01%; $P < 0.01$). Steaks cooked CS and SV0 were similar for WBSF (3.2 and 3.4 ± 0.17 kgf; $P = 0.56$) and had lower WBSF than SV30, SV60, and SV90 (3.8, 3.9, and 3.8 ± 0.17 kgf; $P \leq 0.05$).

Conclusion: Sous vide cookery can produce similar WBSF values, with less cook loss, when compared with clam shell cooking when steaks are removed when they reach 71°C. Holding steaks in sous vide at 72.5°C for 30 to 90 additional minutes increased WBSF and cook loss; however, all steaks fell within the very tender threshold.

Keywords: beef, sous vide, tenderness

## 69 ASSESSMENT OF MICROBIAL POPULATION DYNAMICS IN FRESH GROUND MEAT USING CULTURE-DEPENDENT AND INDEPENDENT MICROBIOLOGICAL ANALYSIS

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Objectives: Fresh ground meat, and in particular beef, is one of the most widely consumed meat products among American consumers. It is estimated that 40% to 45% of all beef is consumed as ground beef. Fresh ground meat is highly perishable with a short shelf life, resulting in more than 20% of this expensive product wasted annually. Characterization of the microbial populations of minced meat as well as their dynamics over shelf life is important to develop targeted preservation strategies to enhance shelf life and reduce food waste.

The aim of this study was to compare and contrast the microbial populations and their dynamics over shelf life in fresh ground beef, pork, and poultry and to investigate the effect of different preservatives, both traditional (Lactate/Lactate-DiAc) and "clean-label" (Kerry's DuraFresh and Provian solutions).

Materials and Methods: Samples were prepared with and without interventions and analyzed in triplicate over 6 timepoints (14 d). Samples were stored at 5°C under modified atmosphere (70:30 $O_2$:$CO_2$-beef and pork, 70:30 $N_2$:30% $CO_2$-poultry). Both culture-dependent (APC/TVC, LAB, *Enterobacteriaceae* and *Pseudomonas*-ISO methods) and culture-independent (16S rDNA amplicon sequencing) analyses were performed. Relative abundance plots were created in R using OTUs (operational taxonomic units) classified to the genus level. Median values of abundance were calculated for each meat sample per timepoint across the replicates sequenced. Any OTUs present at <1% were combined into a category termed "Other."

Results: Starting microbial counts of fresh ground meat samples showed counts of 5.0 (beef), 3.75 (pork), and 4.0 (poultry) Log CFU/g. The initial microbial diversity was relatively high in beef and poultry but low in pork. The most abundant bacteria differed significantly between samples, with *Carnobacterium*, *Brochothrix*, and *Pseudomonas* most abundant in beef, *Photobacterium* most abundant in pork, and *Lactobacillus* and *Lactococcus* most abundant in poultry. During storage an increase in microbial counts coincided with a dramatic decrease in bacterial diversity in both beef and poultry samples. Conversely, an increase in diversity was observed in pork samples. At the end of the storage period almost all samples, including those with interventions, showed microbial counts above the spoilage level of 6 Log CFU/g. All interventions extended shelf life compared with the control with the Kerry's acetate-based solutions demonstrating equivalence or better compared with the industry standard Lactate/Lactate-DiAc. Interestingly, the shift in microbial abundance over shelf life differed depending on the substrate and intervention used. In beef, *Brochothrix* dominated in the Control and Lactate samples on Day 14 (≥ 75%), whereas in the remaining samples, containing acetate-based solutions, *Lactobacillus* dominated (≥ 60%). In the pork and poultry samples, all samples containing interventions diverged from the control with *Lactobacilllus* dominating at end of shelf life (≥ 75%).

Conclusion: This work demonstrates the importance of implementing both culture-dependent and independent methods to understand the true microbial populations and their dynamics in order to optimize preservation strategies for fresh meat products. Our results demonstrate that clean-label interventions are viable alternatives to traditional preservatives to maintain the quality and safety of fresh meat products.

Keywords: antimicrobial, clean label, fresh meat, metagenomics, spoilage

## *70 USING LIQUID SMOKE ON DRY-CURED HAM TO CONTROL TYROPHAGUS PUTRESCENTIAE INFESTATION AND ITS IMPACT ON DRY-CURED HAM QUALITY*

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Objectives: The USDA considers dry-cured hams adulterated if mites (*Tyrophagus putrescentiae*) are present at any time during production. Methyl bromide had been widely used against insects but now can only be used under "critical use exemption." Therefore, the objective of this research was to evaluate the efficacy of liquid smoke in controlling mite growth and its effects on the quality attributes of dry-cured hams.

Materials and Methods: The food-grade ingredients included liquid smoke Supreme Poly (SP) and Select 24P (24P), xanthan gum (XG), and propylene glycol (PG). Experimental coatings applied to small ham cubes or into ham nets included (1) 1% SP + 1% XG, (2) 2% SP + 1% XG, (3) 1% SP only, (4) 2% SP only, (5) 1% XG + 20% PG, (6) 2% 24P + 1% XG, (7) 1% 24P only, (8) 2% 24P only, (9) 1% XG + 20% PG, and (10) untreated control. Each coating solution was applied to ham cubes ($n_{cubes}$ = 5/trt., 2.54 × 2.54 × 2.54 $cm^3$) or infused in ham nets and cut (14.5 × 13 $cm^2$) to wrap around dry-cured ham cubes. Twenty mixed-sex adult mites were inoculated on the cubes. The experimental cubes were each placed in a ventilated glass jar and then stored in an environmental chamber at 24°C and 75% RH for 2 wk, and then the final number of living mobile mites on each cube was counted. A sensory difference from control test was used to evaluate their impact on the sensory attributes of ham slices. A 4-point scale where 0 = no difference to 4 = very large difference was used to

evaluate the differences between the treatment and the control ham. Simultaneous experiments were conducted with noninoculated ham cubes to evaluate water activity ($a_w$), moisture content, and weight loss change of the ham cubes treated with treatments in comparison with the control after 2 wk. The selected solutions were those that exhibited the ability to control mite growth ($n_{mites} < 20$ after 2 wk). Randomized complete block designs were used to determine the effect of different treatments on ham mite growth (2 reps), sensory evaluation (2 reps), water activity (2 reps), moisture content (2 reps), and weight loss (2 reps). Duncan's new multiple range test was used to separate treatment means when significant differences ($P < 0.05$) existed among treatments.

Results: The addition of liquid smoke (SP and 24P) to the XG coatings enhanced ($P < 0.05$) mite controlling efficacy. When 1% SP was added to 1% XG, it effectively controlled mite growth ($P < 0.0001$) in both coating and netting treatments. Both coating and netting treatments with 2% 24P + 1% XG controlled mite growth ($P = 0.0039$). Both 1% and 2% 24P treatment-controlled mites ($P < 0.05$) when infused into net. The addition of SP did not impact ($P > 0.05$) the sensory attributes of the dry-cured ham. The 2% 24P + 1% XG treatment had a slight to moderate difference (value = 1.56) when compared with the control. The final water activity values of all treatments were within the market range of 0.74 to 0.93. The moisture content of SP-treated cubes were not different ($P > 0.05$) from that of net control. SP and 24P treatments had similar weight loss when compared with the control ($P > 0.05$), indicating that yields would not be impacted by using liquid smoke.

Conclusion: Overall, results from these studies indicated that liquid smoke can potentially be added in coatings or ham nets to help control mite infestations in an integrated pest management program for dry-cured hams.

Funding Source: United States Department of Agriculture Methyl Bromide Transition Program (award number 2015-51102-24143).

Keywords: dry-cured ham, ham mite, liquid smoke, sensory quality

## 71 EVALUATING STACKED PROCESSING TO IMPROVE WOODEN BREAST FUNCTIONALITY AND TENDERNESS

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Objectives: Wooden breast myopathy has plagued the poultry meat industry and is a major source of lost revenue opportunity. Wooden breast is characterized by infiltration of connective and adipose tissue and rigidity leading to a product that is less tender and has lower protein functionality. Further processing has been explored to mitigate the effects of wooden breast with moderate success; however, stacked processing, the combination of multiple further processes, has not been explored. The objective of this research was to determine if stacked processing could ameliorate negative properties associated with wooden breast myopathies.

Materials and Methods: For each of 3 replications, 50 breast fillets representing normal (NORM), moderate (MOD), and severe (SEV) wooden breast classifications (150 in total) were identified by commercial plant personnel and delivered to the University of Georgia Meat Science Technology Center (MSTC). Three trained MSTC personnel confirmed and selected 20 breast fillets by manual palpation from each severity classification for inclusion. Within severity, fillets were randomly assigned to further processing treatment including control (CON; no processing), blade tenderization (BT), BT plus vacuum tumble marination (BTM), or BT followed by multineedle enhancement and vacuum tumble marination (BTIM). The BTM and BTIM targeted a 10% pickup with 0.75% NaCl and 0.3% sodium tripolyphosphate. Postprocessing samples were cooked and subjected to multiblade shear force analysis. Data were analyzed as a mixed model (SAS 9.4) with severity and processing treatment as fixed effects with replication as the random term.

Results: Initial breast characteristics indicated that subjective palpation accurately segregated samples based on severity, with NORM having lower cranial compression scores than MOD, which were lower than SEV ($P < 0.01$; 21.5, 33.4, and 50.1 N, respectively). White striping and hemorrhagic lesion scores increased with severity ($P < 0.01$). Initial breast pH was greater for MOD and SEV than NORM ($P < 0.01$), and SEV had greater total and insoluble collagen content than NORM or MOD ($P < 0.01$). There was not a severity by processing interaction for marination retention ($P = 0.68$), but NORM had greater retention (8.3%) than MOD (6.6%) and SEV (4.9%), which were also different ($P < 0.01$). Additionally, BTIM had greater retention than BTM ($P < 0.01$). There was a percent cook loss interaction ($P = 0.03$) in which BTIM samples had less cook loss than CON and BT samples, whereas BTM was intermediate for NORM ($P > 0.05$), less than CON and BT for MOD ($P < 0.01$), and similar to CON for SEV ($P > 0.05$). There was not a severity by processing interaction for multiblade shear force ($P = 0.11$) but there was a severity main effect with NORM ($P < 0.01$). Additionally, BTIM had lower shear force than BT ($P < 0.01$) with all other processing treatments being similar ($P \geq 0.06$).

Conclusion: Overall, stacked processing was not able to overcome the inherent tenderness hurdles presented by the wooden breast myopathy. However, BTIM was able to increase marinade retention, and both BTM and BTIM

exhibited less cook loss than nonprocessed or blade tenderized samples.

Funding Source: USDA – NIFA.

Keywords: poultry, tenderness, woody breast

## 72 THE EFFECTS OF VARYING LEAN POINTS AND PACKAGING METHODS ON GROUND BEEF SENSORY TRAITS AND LIPID OXIDATION IN A RETAIL SETTING

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Objectives: The objectives of this study were to (1) measure sensory transformations between lean points and retail packaging methods to determine overall acceptance in regard to case life, (2) compare lipid oxidation accumulation in lean points and retail packaging methods over display time, and (3) determine optimal retail packaging methods for ground beef against a targeted lean point.

Materials and Methods: Samples ($n = 207$) comprised of USDA Choice knuckles and shoulder clods were ground and blended to represent 3 lean point treatments: high, medium, and low (94%, 86%, and 78% lean, respectively). Lean point treatments were equally represented among 3 packaging methods, overwrap tray, clear chub, or white chub, providing varying levels of light and oxygen. Samples were designated for removal from retail display on 1 of 6 d (1, 2, 3, 6, 7, and 8) for trained sensory, cooked color, cook loss, and lipid oxidation evaluation. Trained sensory panelist evaluated 9 samples/panel (17 panels) for juiciness, overall tenderness, firmness, cohesiveness, beef flavor intensity, and off-flavors. Objective cooked color was evaluated using a HunterLab MiniScan. The thiobarbituric reactive substances assay (TBARS) was performed to determine lipid oxidation levels among treatments (mg MDA/kg meat).

Results: Packaging and lean point treatment interactions over the course of retail display provided sensory trait differences for all off-flavor interactions as well as varying differences among packaging methods for juiciness ($P < 0.05$). All other sensory attributes were not significant ($P > 0.05$). In both significant instances, over the course of retail display, the vacuum-chub packaging methods (white and clear) outlasted the overwrap tray packaging method in positive juiciness and off-flavor attributes. Lean point treatments of ground beef samples significantly impacted the day of detection and level of off-flavors. High lean point samples, regardless of packaging method, outlasted the low lean point treatment regarding off-flavor detection, especially when packaged in the overwrap tray method ($P < 0.05$). Differences among cooked redness values ($a^*$) across packaging methods occurred day 2, 3, 6, and 7, in which redness favored both chub methods ($P < 0.05$). Moreover, the overwrap tray method delivered lighter ($L^*$) cooked color values ($P < 0.05$). Interactions over the course of retail display for overall cook loss percentages were not significant ($P > 0.05$). Lipid oxidation was significantly affected by the packaging method and lean point across days ($P < 0.05$). Samples packaged in overwrap trays had much greater oxidation levels, especially for the high lean point treatment. As early as Day 1, increased lean point provided significantly higher levels of lipid oxidation.

Conclusion: The role of varying lean points and packaging methods impact ground beef sensory traits and lipid oxidation over the course of retail display. Vacuum-style chubs prove to sustain favorable sensory attributes over time in a retail setting when compared with overwrap tray packaging, especially as fat level increases. Minimal differences occurred between clear and white chubs regarding sensory traits, cooked color, and lipid oxidation.

Keywords: ground beef, oxidation, packaging, retail display, sensory evaluation

## 73 DETERMINATION OF OPTIMUM FREEZING PRATICES OF BEEF STEAKS

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Objectives: Frozen vacuum-packaged beef offers consumers flexible handling and storage and expands markets for processors; however, consumers find the appearance of frozen beef to be less desirable. Currently, there is a lack of research on how the exposure of whole muscle steaks to oxygen (bloom time [BT]) and to vacuum and refrigeration (hold time [HT]) prior to freezing affects myoglobin status and perceived color. This study evaluates various BT and HT in package before freezing to determine the greatest impact on perceived meat color and myoglobin forms.

Materials and Methods: Twenty-nine "A" maturity USDA low Choice carcasses were identified. Strip loins and top butts were collected, then held under vacuum at 2°C until 18 d postmortem. Subprimals were cut to yield nine 2.5-cm steaks and were randomly assigned to 1 of 9 freezing protocols representing combinations of BT (0, 15, 60 min) × HT (0, 3, 24 h). Steaks ($N = 522$) were cut and allowed to bloom for their designated time, then individually vacuum packaged in roll stock film. Steaks were held for their designated time and then frozen at −20°C. Beef color was evaluated by trained panelists for redness, brightness, and discoloration, and instrumental color measurements (CIE $L^*$, $a^*$, and $b^*$) were obtained during the freezing process (2, 6, 12, 24 h). After 1 wk of frozen storage to model shipping, steaks were evaluated in the frozen state and then

tempered at 4°C. After tempering, thawed steak color was evaluated while vacuum packaged and then again following opening the package and a 15 min bloom period. This study was a complete randomized block design, and the visual panel and instrumental assessment were analyzed to define the effects of BT × HT combinations by time intervals and their interaction. Treatment combinations by time was the only fixed effect in the model ($\alpha = 0.05$).

Results: Freezing protocols were different over time for visual ($P \leq 0.01$) and instrumental color ($P \leq 0.01$). After the freezing process, 60 × 3, 15 × 3, and 60 × 24 had the greatest amount of discoloration ($P < 0.01$) at the 24 h time interval. The 60 × 0 had the reddest color ($P < 0.01$) and the 15 × 3 and 0 × 3 were the darkest ($P < 0.01$) at the 24 h interval. The 60 × 0 were the brightest ($P < 0.01$) for all time intervals measured during the freezing process. Instrumental redness ($a^*$) was greater in the 60 × 0 treatment ($P < 0.01$). The 60 × 0 had the lowest discoloration value after 1 wk storage and the greatest value after thawed ($P < 0.01$). The 24 h hold treatments were the darkest in color ($P < 0.01$). The 60 × 0 steaks were fully discolored at the thaw and 15 m bloom intervals. After thawing, the 60 × 0 indicated the least color stability with the lowest $a^*$, and the greatest $L^*$ and $b^*$ ($P < 0.01$). In contrast, the 0 × 24 had the greatest $a^*$ ($P < 0.01$) value at the thaw and 15 m bloom intervals.

Conclusion: The most divergent combinations of extended BT and short HT created the brightest, reddest frozen color. However, those same steaks exhibited the least color stability after being thawed. Conversely, divergent combinations of short BT and extended HT produced the darkest frozen color, but greatest color stability once thawed.

Funding Source: Funded by Beef Checkoff and JBS.

Keywords: beef color, bloom time, freezing, hold time, stability

## 74 EFFECT OF PARSLEY POWDER AS A SOURCE OF NITRATE ON SOME CHARACTERISTICS OF UNCURED FERMENTED SAUSAGE

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Objectives: Concern about sodium nitrite ($NaNO_2$) has driven increased demand for uncured versions of traditionally cured meat products. Thus, natural sources of nitrate have been used in uncured meat including celery juice, cranberry powder, parsley powder, and parsley extract powder. However, nitrate concentration can vary among natural sources because of factors such as their species and the regions where they were grown. Moreover, the use of vegetable powders or elimination of $NaNO_2$ may lead to changes in product properties. This study aimed to evaluate the nitrate concentration in several parsley powders to use as a natural source of nitrate ($NO_3^-$) and determine the effect of the direct addition of parsley powder on pH and color in fermented summer sausage.

Materials and Methods: The parsley powders were sourced from 5 different countries: the United States, Egypt, China, Israel, and Lithuania. Furthermore, to study the effect of parsley powder on some quality characteristics of fermented beef summer sausage, there was one control product (LN) with lactic acid bacteria (LAB), *Pediococcus cerevisiae* and *Lactobacillus plantarum*, and $NaNO_2$, and 4 test products formulated with meat, seasonings, and test ingredients as follows: parsley powder with *S. carnosus*, without $NaNO_2$ (SP), parsley powder with *S. carnosus* and LAB, without $NaNO_2$ (SLP), *S. carnosus* with LAB without parsley or $NaNO_2$ (SL), and *S. carnosus* alone, without $NaNO_2$ (S). The samples were incubated for 24 h at 40°C with pH measurement every 6 h and color measurement following fermentation, 7, and 21 d of storage at 4°C. The SPSS software version 23 was used for analysis. Two-way ANOVA was used to determine the effect of different treatments and storage times on the pH and color ($L^*$, $a^*$, $b^*$) values. Moreover, when significant interaction effects were identified ($P > 0.05$), separation of means was conducted using Tukey.

Results: The results showed that the nitrate concentrations varied among the countries. They ranged from 139.4 ppm in Lithuania to 3,218.93 ppm in Egypt. The parsley containing the highest nitrate level (3,218.93 ppm) was used in this experiment. The initial pH of all treatments was about 5.59. After 6 h, there was no difference ($P > 0.05$) among treatments, with pH values ranging from 5.56 to 5.52. Furthermore, there was a decline in the pH level in the treatments inoculated with LAB after 12, 18, and 24 h. The lowest pH was observed with SL, and the highest was the S treatment. Moreover, the redness for SLP was significantly increased after incubation to reach the highest in 21 d (from 7.49 ± 1.03 to 8.56 ± 1.09). At 21 d, there was no difference in redness ($P > 0.05$) between the LN and the SLP ($a^*$ values were 9.35 ± 2.17 and 8.56 ± 1.09, respectively), whereas they were significantly different from other treatments. Lightness and yellowness showed significant ($P < 0.05$) change after 21 d in all treatments except SLP.

Conclusion: In conclusion, the nitrate concentration of parsley powders must be determined before using in the Uncured meat products formulation. The direct addition of parsley powder with *S. carnosus* and LAB gave similar pH and color stability to the product made with $NaNO_2$. Parsley powder may be a suitable ingredient for manufacturing certain "Uncured" fermented meat products.

Keywords: parsley powder, sodium nitrite, uncured fermented sausage

## 75 EFFECT OF AGING, FREEZING, AND THAWING ON WATER LOSS AND QUALITY OF BEEF SKIRTS AND SIRLOIN BUTTS

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Objectives: Food service meat purveyors subject beef cuts to various processes during production which can impact meat quality. The objective was to evaluate the effects of aging, freezing, and thawing on quality attributes of beef skirt steaks and sirloin butts. Understanding these effects is important because they can have downstream effects for both the consumer and processor.

Materials and Methods: Vacuum-sealed packages of US Choice top butts ($n = 80$) and Canadian Grade A peeled outside skirts ($n = 80$) were collected and sorted into 8 equal experimental groups. Groups were designed to create every combination of the following treatments: a 21 d short-age (SA) or a 50 d long-age (LA), conventional freezing (CF), or flash freezing (FF), and thawing in a hot-water bath at 23°C (HW) or a prechilled-water bath at 17°C (PW). Packages were maintained at 4°C during aging, frozen for at least 1 wk, thawed for 18 h, and weighed for purge loss. Two steaks were collected from each of 3 randomly selected packages from each experimental group, totaling 6 steaks. These were individually vacuum sealed, brought to the University of Florida, and evaluated after an additional 10 or 20 d aging period at 4°C. For each secondary aging period, one steak per group was weighed for purge loss and cooked to 71°C for cook loss and sensory analysis. One steak was swabbed to inoculate nonselective TSA plates. Plates were incubated for 24 h to obtain total plate count (TPC). The third steak was evaluated for off-odors, measured for color with a HunterLab colorimeter, and grilled to 71°C for slice shear force. Statistics were run in SAS using the proc mixed method.

Results: The SA and FF skirt packages had more purge loss ($P = 0.03$) than any other age/freeze combination. There were no other differences in any water loss measure in skirt steaks between treatments. Skirt steaks thawed in HW baths displayed stronger ($P = 0.04$) off-odor than steaks thawed in PW. Skirt steaks from all treatments displayed a high degree of off-flavor, though there was no difference between treatments. No difference was reported for any other sensory characteristic between skirt steak treatments. There was a three-way interaction ($P = 0.048$) on TPC for skirts. The effect is not apparent but may be primarily attributed to LA steaks having a higher TPC ($P = 0.054$) than SA steaks as well as a freezing by thawing interaction ($P = 0.054$). The SA top butt packages had more purge ($P = 0.001$) than LA packages. Freezing and thawing treatments did not impact any water loss measure in top butts. The LA sirloin steaks had a stronger beef flavor ($P = 0.04$) than SA steaks, and HW steaks had a stronger beef flavor ($P = 0.005$) than PW steaks. The LA sirloin steaks were darker ($P = 0.01$) and redder ($P = 0.04$) than SA steaks and FF steaks were darker ($P = 0.01$) than CF steaks. No treatments impacted TPC for top butts.

Conclusion: Aging is shown to have an effect on purge loss; however, the effect is inconsistent between the subprimals tested. The sirloin steaks showed quality differences that we would expect, with longer aged beef having a stronger beef flavor and redder color, along with differences from thawing and freezing treatments. However, none of these quality differences appear in skirts. This is possibly due to skirts innately having poorer shelf life as compared with sirloins, which likely resulted in more off-flavors. Additional testing should be done before making conclusions.

Keywords: aging, beef quality, freezing, thawing

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## 76 EFFECTS OF THE DIETARY CONCENTRATE LEVEL ON MEAT COLOR TRAITS OF SPANISH WETHER AND DOELING CARCASSES

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Objectives: From 1987 to 2019, the number of meat goats produced in the United States has increased steadily from 415,196 to 2,622,000 (USDA NASS). Meat color is one of the most important factors influencing consumers' purchasing decisions (Mancini and Hunt, 2005). Therefore, the objective of the study was to determine effects of dietary concentrate level on meat quality traits of Spanish wether and doeling carcasses.

Materials and Methods: At approximately 4 mo of age, 58 (29 wethers and 29 doelings) goats were weaned and randomly assigned to 1 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 ingredients, 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 10 mo of age. Temperature and pH decline were monitored throughout the 48 h chilling time for all carcasses. Carcasses were ribbed and color measurements were taken 15 min after to allow for blooming. Flank streakings and color were evaluated using the guidelines from the Meat Goat Selection, Carcass Evaluation and Fabrication Guide from Louisiana State University. One sirloin chop was taken from

the anterior portion of the leg and subjected to 3 d in retail display. During display, muscle color, surface discoloration, and overall acceptability was measured by a trained 6-member panel, and objective $L^*$, $a^*$, and $b^*$ values were recorded with a HunterLab Miniscan Spectrophotometer.

Results: Flank color and flank streakings did not differ ($P > 0.05$) between diets or sex. Temperature and pH declined steadily over the 48 h period as expected. Additionally, pH remained higher ($P < 0.05$) from wether carcasses than doeling carcasses regardless of diet. Loin pH was higher ($P < 0.05$) in the goats fed 20C than all other diets. Carcasses from goats fed the 20C, 50C, and 70C diets had higher $a^*$ values compared with carcasses from goats fed the 60C diet. Also, as expected $a^*$ values decreased ($P < 0.05$) as retail display increased regardless of diet fed. Lightness scores, $L^*$ values, were higher ($P < 0.05$) from sirloin chops fabricated from females on retail day 1 and 2 than males. $L^*$ values of sirloin chops from goats fed the 60C diet were higher ($P < 0.05$) than the goats fed 40C diet on retail day 0 and 1 as well as higher than the goats fed 50C diet on retail day 1. Chops from goats fed 60C diet were lighter ($P < 0.05$) than chops from goats fed 50C or 70C on retail day 2. Muscle color was darker ($P < 0.05$) from chops fabricated from female carcasses compared with males on retail day 1 and 2. Overall acceptability decreased as retail day increased. Chops from doeling carcasses had lower ($P < 0.05$) acceptability scores than chops from wether carcasses on retail day 1 and 2, with no difference at the beginning of display. Overall acceptability of chops from goats fed 40C, 50C, and 70C diets was higher ($P < 0.05$) on retail day 2 than chops from goats fed 20C and 60C diets. Surface discoloration increased ($P < 0.05$) throughout retail display for all diets and sexes.

Conclusion: In conclusion, there was no consistent trend for quality traits of temperature, pH decline, carcass quality, or display color of carcasses or chops from goats fed varying concentrate diets.

Funding Source: American Institute for Goat Research, Langston University, Langston, Oklahoma.

## 77 EVALUATION OF SUSPENDED FRESH ON BEEF RETAIL SHELF LIFE AND QUALITY CHARACTERISTICS

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Objectives: Extending the shelf life of fresh meat without any adverse effect on meat quality attributes is critical to the meat industry to reduce waste, stabilize supply, and facilitate export shipments. A patented, proprietary, trademarked program called Suspended Fresh (SF) allows the storage of beef subprimals slightly above their freezing point to slow down the growth rate of spoilage microflora and continue postmortem tenderization while maintaining its fresh status. However, the shelf life and quality characteristics of beef following SF storage is not known. Therefore, the objective of this study was to evaluate the effect of 60, 75, and 90 d of SF storage on retail shelf life and quality characteristics of beef inside rounds (IR), bone-in ribeyes (RE), and striploins (SL).

Materials and Methods: Subprimals (IR, RE, and SL) were collected from 10 ($n = 10$) paired upper 2/3rd Choice beef carcasses. Two 2.54-cm steaks fabricated from each subprimal were vacuum packaged, wet-aged (3°C; 21 d), and then frozen (−20°C) pending Warner-Bratzler shear force (WBSF) and consumer sensory analyses. The remaining intact subprimals were cut, individually vacuum packaged, and randomly assigned to an SF storage period (−3°C ± 0.5°C; 60, 75, or 90 d). Following each SF storage period, 5 steaks were fabricated from the subprimal pieces, overwrapped, and placed in a retail display case (3°C) under continuous fluorescent light for 7 d. Another 2 steaks were vacuum packaged and stored (−20°C) until WBSF and consumer sensory evaluations. Consumers ($N = 238$) evaluated each sample for juiciness, tenderness, flavor liking, and overall liking. Instrumental and trained visual color were evaluated daily during retail display, and aerobic microbial populations (APC), lactic acid bacteria, and *Pseudomonas* spp. were enumerated on days 0, 2, 4, and 7. Data were analyzed in R (3.5.1) using a split-plot design (instrumental color, visual color, WBSF, and sensory evaluation) or factorial design (microbial counts). Least-squares means were separated using a significance level of $\alpha = 0.05$.

Results: For all cuts, initial (day 0 of retail display) redness ($a^*$) and yellowness ($b^*$) values of 60-d SF steaks were lower ($P < 0.05$) than 75-d and 90-d SF steaks. Regardless of SF storage time or retail display day, in general, trained visual color assessments revealed no differences ($P > 0.05$) in lean color and discoloration of steaks. For all 3 subprimal cuts, APC of 60-d SF steaks on days 0, 2, and 4 of retail display were lower ($P < 0.05$) than APC of corresponding 75-d and 90-d SF samples. WBSF values decreased ($P < 0.05$) with storage time for all cuts. Consumer tenderness scores of IR and SL increased ($P < 0.05$) with extended SF storage time. For IR, tenderness scores of 75-d SF samples were higher ($P < 0.05$) than samples subjected to 21 d of wet aging. For SL, tenderness scores of 90-d SF samples were higher ($P < 0.05$) than those of 60-d SF steaks, but similar ($P > 0.05$) to tenderness scores of 21-d wet-aged samples. Irrespective of cut, no differences ($P > 0.05$) in juiciness, flavor liking, and overall liking of samples were observed between the storage times.

Conclusion: The results of this study suggested SF storage could extend the shelf life of fresh beef while preserving or even improving product sensory attributes. Findings of this study can be useful for the meat industry when considering extending the storage of beef under low controlled temperatures.

Funding Source: National Cattlemen's Beef Association.

Keywords: extended chilled storage, meat color, sensory evaluation, shelf life, tenderness

## 78 EVALUATING THE OCCURRENCE OF PERSISTENT PINKING IN GROUND BEEF PATTIES OF DIFFERING FAT PERCENTAGES PACKAGED IN CARBON MONOXIDE MODIFIED ATMOSPHERE PACKAGES

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Objectives: The objective of this study was to gain a better understanding of the occurrence of persistent pinking by evaluating ground beef with different fat percentages packaged with carbon monoxide modified atmosphere packaging (CO-MAP).

Materials and Methods: Three cases of fine ground beef (IMPS 136) with targeted lean/fat percentages of 73/27, 81/19, and 93/7 were collected from a commercial packing facility. Ground beef was stored for 10 d. After storage, each ground beef chub was opened and reground with a 3 mm stainless steel grinder plate together to form one composite batch of each fat percentage. After grinding, 225 g patties were weighed, formed utilizing a patty maker, and placed onto foam trays ($n = 81$) with an absorbent pad and overwrapped with polyvinylchloride film (PVC). The trays were randomized within each fat percentage and were then placed in master bags ($n = 27$) in groups of 3 with one oxygen scavenger per bag. Twenty-seven master bags were flushed with a tri-gas blend of 0.4% CO, 30% $CO_2$, and balance $N_2$. Master bags were then held in dark storage until pull day: 1 d, 8 d, or 15 d. On each pull day, 9 master bags were removed from dark storage, and the trays were placed in a display case for retail display evaluation for 3 d. Headspace analysis was conducted before each master bag was opened. Instrumental and objective color measurements were collected on days 0 to 2 of retail display. Visual color and surface discoloration were analyzed daily by a trained panel ($n = 6$). The formation of carboxymyoglobin (COMb) was confirmed by measuring ratio of absorbance at 543 nm/581 nm. Patties were cooked to an internal temperature of 71°C. Internal cooked color was evaluated by a trained panel ($n = 6$) along with instrumental color reading postcooking.

Results: The pH of all blends was consistent with normal ground beef at grinding and on each pull day. The results of the study showed the 93/7 patties had higher $a^*$ values throughout retail display over all pull days. All patties had formed COMb by retail display, regardless of storage day or fat percentage. The 93/7 patties had consistently browner internal subjective cooked color scores compared with the 73/27 patties. The 73/27 patties from all pull days were significantly ($P < 0.05$) redder than the 93/7 patties, and on pull day 1 and 15, the 81/19 and 73/27 patties had significantly ($P < 0.05$) redder cooked $a^*$ values than the 93/7 patties. COMb was formed in CO-MAP regardless of ground beef fat percentages or pull day. Additionally, ground beef with more fat (73/27) had more pinking after cooking to recommended internal temperature compared with lower fat blends.

Conclusion: With consumer confusion on pinking within meat products postcooking, further research should be conducted to better understand the relationship of fat content of ground beef and dark storage times resulting in persistent pinking.

Keywords: carboxymyoglobin, modified atmosphere packaging

## 79 COMPARISON OF NOVEL PORK CUTS FROM SHOULDER AND HAM OF HEAVIER PIGS TO LOIN CHOPS SOURCED FROM CONTEMPORARY PIGS

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Objectives: The goal was to determine if chops from *serratus ventralis* (SV), *triceps brachii* (TB), and *semimembranosus* (SM) of heavier pigs were similar in tenderness, juiciness, and flavor to center-cut *longissimus dorsi* (LD) chops of contemporary market weight pigs.

Materials and Methods: Pigs ($N = 48$) from 3 different genetic lines were categorized based on hot carcass weight (HCW): light (99–109 kg), medium (116–126 kg), and heavy (134–144 kg). Pigs were slaughtered under university conditions and chilled at 4°C for at least 20 h. The SV, TB, SM, and LD were collected from carcasses and cut into 2.54 cm chops. pH and $L^*$, $a^*$, and $b^*$ were recorded (Minolta CR-400 Chroma Meter colorimeter, 2° observer, 8 mm closed aperture, and D65 illuminant). Chops were aged for 14 d at 4°C before freezing at −20°C. Chops were allocated to panels such that each panel contained medium and heavy SV, medium and heavy TB, medium and heavy SM, and light LD. Chops were thawed at approximately 4°C for 24 h prior to cooking, then cooked to an internal temperature of 63°C on Farberware open-hearth grills with constant temperature monitoring. Six panelists scored chops for tenderness, juiciness, and pork flavor on a 15-cm semistructured line scale anchored at 7.5 cm where 0 = extremely tough, extremely dry, or no flavor and 15 = extremely tender, extremely juicy, and very intense flavor. Data were

analyzed as one-way ANOVA with treatment (cut type and weight class) as fixed effects and panel, genotype, and sex as random effects. Differences were considered significant at $P \leq 0.05$.

Results: The pH of the medium TB (5.82), heavy TB (5.91), medium SV (5.86), and heavy SV (5.87) was greater ($P < 0.05$) than that of heavy SM (5.65) and medium SM (5.62) and light LD (5.52). Chops from medium TB ($L^*$ 39.8) and heavy TB ($L^*$ 40.0) were darker ($P < 0.05$) than heavy SV ($L^*$ 42.3) and medium SV ($L^*$ 42.6). All SV and TB were darker than light LD ($L^*$ 48.7), which was darker ($P < 0.05$) than both medium SM ($L^*$ 51.9) and heavy SM (53.3). In terms of redness ($a^*$), medium and heavy SV were more red ($P < 0.05$) than medium and heavy TB and medium and heavy SM, whereas light LD was not different ($P > 0.05$) from TB or SV chops. Therefore, in terms of pH and color, TB and SV chops from medium and heavy pigs had greater pH and were darker than light LD chops, whereas SM chops from medium and heavy pigs had lesser pH and were lighter than light LD. All chops were cut to 2.54 cm in thickness, but chops differed in weight. Medium and heavy SV and medium TB chops were similar ($P > 0.05$) in weight to light LD chops, weighing approximately 180 to 200 g. Heavy TB (223 g), medium SM (289 g), and heavy SM (323 g) were all heavier ($P < 0.05$) than light LD chops. Cook loss did not differ between treatments ($P = 0.15$). Heavy TB and medium SV were slightly more tender ($P = 0.05$) than other chops. All novel cuts were juicier than the light LD ($P = 0.01$), and light LD had the least ($P = 0.01$) flavor among treatments. The heavy and medium TB and heavy and medium SV were similar in flavor ($P = 0.98$) but had more ($P < 0.001$) flavor than heavy and medium SM.

Conclusion: Novel cuts from the SV, TB, and SM were similar in size to LD chops but were more juicy and flavorful. These data suggest that these novel cuts could be explored as potentially valuable additions to pork retail offerings.

Keywords: ham, muscle profiling, novel cuts, shoulder

## 80 EFFECTS OF EXTENDED POSTMORTEM AGING ON COLOR AND REDOX STABILITY OF FIVE BOVINE MUSCLES

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Objectives: Postmortem aging is a common practice to improve beef tenderness and palatability. However, it is generally known that color and lipid oxidative stability worsens during postmortem aging, whereas the extent may differ between individual muscles. Consumers heavily rely on surface meat color to determine meat freshness and subsequent meat purchasing decision. Thus, it is crucial to understand biochemical mechanisms that can be used to develop muscle-specific optimal aging systems to minimize discoloration while maximizing positive impacts of aging on palatability attributes. The objective of this study, therefore, was to determine the impacts of extended postmortem aging on color and redox stability of different beef muscles.

Materials and Methods: Pairs of 5 muscles including *bicep femoris* (BF), *gluteus medius* (GM), *infraspinatus* (IF), *longissimus lumborum* (LL), and *semitendinosus* (ST) were obtained at 1 d postmortem from 16 beef carcasses (USDA Choice). Muscles were divided into 4 equal sections, vacuum packaged, and randomly assigned to 1 of 4 aging periods (2, 21, 42, and 63 d). At the end of each aging period, 2-cm-thick steaks were cut and overwrap packaged with polyvinylchloride film and displayed for 7 d under light for instrumental and trained color panel evaluations. Biochemical analyses including metmyoglobin reducing activity (MRA) and oxygen consumption (OC) were conducted. All treatment levels were analyzed using PROC GLIMMIX procedure of SAS 9.4 to examine the main effects of muscle, aging, and display duration as well as their interactions. Statistical significance level was set at $P \leq 0.05$.

Results: In general, an increase in postmortem aging period resulted in a decrease in color stability of beef steaks, regardless of muscle types based on instrumental color ($a^*$, hue angle, and chroma values) as well as sensory discoloration scores ($P < 0.0001$). Among muscles, however, the LL maintained the highest color stability followed by ST, GM, BF, and IF based on $a^*$ and sensory discoloration values, irrespective of aging periods ($P < 0.0001$). MRA was highest at 21 d postmortem, with ST having the highest MRA followed by no significant difference in BF and LL, then IF and GM ($P < 0.0001$). MRA significantly decreases with aging time, with LL having the highest MRA at 63 d postmortem followed by BF, ST, GM, and IF ($P < 0.0001$). OC was consistent and not significant in BF, GM, LL, and ST as aging time increased. However, IF had a steady increase of OC with increasing aging ($P < 0.0001$).

Conclusion: These data suggest that increasing postmortem aging has detrimental effects on color stability of muscles such as BF, GM, and IF. In particular, the LL was color stable across all aging durations, whereas the color stability of the IF was most labile with aging among beef muscles. The results of the current study indicate the need of establishing muscle-specific optimal aging practice considering different color stability of different beef muscles. Further studies utilizing metabolomics approach and other redox-related attributes to elucidate underlying mechanisms for the muscle-specific oxidative stability to extended aging are currently underway.

Funding Source: USDA-AFRI.

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

## 81 BEEF STEAKS FROM SUBPRIMALS SUBJECTED TO VARIOUS FROZEN/ REFRIGERATED STORAGE CONDITIONS

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Objectives: Objectives were to determine the effect of refrigerated and/or frozen storage on beef subprimals and steaks.

Materials and Methods: USDA Choice ribeye rolls and top sirloin butts were used in this study. After postfabrication aging time (21 d), ribeye rolls ($n = 10$), and top sirloin butts ($n = 10$) were assigned to 1 of 4 storage treatments:

(1) Frozen/Frozen. Subprimals were frozen (−28.9°C) for 30 d, thawed for 7 d under refrigeration (−1.1°C), and portioned into steaks, which were frozen (−15.2°C) for 30 d. After 30 d, steaks were thawed for 2 d under refrigeration (−1.1°C) and evaluated within 7 d, totaling approximately 98 d of storage.

(2) Frozen/Refrigerated. Subprimals were frozen (−28.9°C) for 30 d, thawed for 7 days under refrigeration (−1.1°C), and portioned into steaks, which were evaluated within 7 d of cutting, totaling approximately 65 d of storage.

(3) Refrigerated/Frozen. Subprimals were portioned into steaks, and steaks were frozen (−28.9°C) for 30 d. Steaks were thawed for 2 d under refrigeration (−1.1°C) and evaluated within 7 d of thawing, totaling approximately 60 d of storage.

(4) Refrigerated/Refrigerated. Subprimals were portioned into steaks and were evaluated within 7 days of cutting, totaling approximately 28 d of refrigerated (−1.1°C) storage.

Measurements including purge, color, cooking yields, tenderness, and consumer acceptability were taken from steaks. Steaks ($n = 240$ total) were cooked on a Star commercial flat-top grill preheated to 177°C ± 3°C. Internal steak temperatures were monitored during cooking using ThermaData Type-T Thermocouple loggers, and 0.02-cm-diameter copper-constantan Type-T thermocouple wires inserted into the geometric center of each steak. Steaks were cooked to 35°C, flipped, and cooked to a final internal temperature of 70°C. Consumer sensory panel procedures were approved by the Texas A&M Institutional Review Board for the Use of Humans in Research (protocol number: IRB2019-1458M). Panelists ($n = 80$) assessed 8 samples, and each sample was evaluated by 4 panelists. Panelists were asked to evaluate the samples using 9-point scales.

Results: For top sirloin butts, the Frozen/Frozen and Frozen/Refrigerated treatments ($P = 0.0067$) had the greatest subprimal purge percentage compared with the other treatments. For both subprimal types, there were differences ($P < 0.0001$) between storage treatments for steak purge percentage. Frozen/Refrigerated ribeye and top sirloin steaks treatment had among the highest steak purge percentages, whereas Refrigerated/Refrigerated had the lowest. Ribeye and top sirloin steaks from Refrigerated/Refrigerated resulted in the greatest ($P < 0.0001$) cook yield compared with all other treatments. There were no differences ($P > 0.05$) in cook time among storage conditions for either steak type. Ribeye steaks from Frozen/Frozen had the greatest WBS force values compared with the Refrigerated/Frozen and Refrigerated/Refrigerated treatments. Consumer panelists rated Frozen/Frozen top sirloin butt steaks lower ($P < 0.05$) than other treatments for overall liking, flavor, and juiciness.

Conclusion: Storage conditions played a greater role for quality and consumer acceptability for top sirloin steaks than ribeye steaks. Overall, freezing subprimals and steaks posed the greatest challenge in quality and palatability.

Funding Source: This research project was funded in part by The Beef Checkoff.

Keywords: beef, consumer acceptability, frozen, refrigerated, tenderness

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## 82 PORCINE STUNNING METHODS AND CARCASS VASCULAR RINSING EFFECTS ON MEAT QUALITY

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Objectives: Objectives were to determine the impact of stunning methods and carcass vascular rinsing on pork meat quality.

Materials and Methods: Market hogs ($N = 48$; average liveweight 122 kg; Duroc, sire; Landrace × Large White, dam) were used to evaluate stun methods (STUN: carbon dioxide gas, $CO_2$; electrical, head-to-body, ES) and chill treatments (CHILL: RC, vascularly rinsed, based on 10% live weight; control, CN, not rinsed). Hogs were harvested on 3 different weeks. Hogs (8 gilts, 8 barrows) were randomly assigned to each of the 4 treatment groups: CRC ($CO_2$ stun + RC chill), ERC (ES stun + RC chill), CC ($CO_2$ stun + CN chill), and EC (ES stun + CN chill). Immediately after bleeding was initiated, RC carcasses were vascularly rinsed (5°C: 98% water; balance: dextrose, maltose, phosphates). Carcasses were scalded, eviscerated, and spray-cabinet washed (water, 38°C) before entering a spray-chill cooler (1°C; 1.5 min on, 15 min off) for 8 h. Carcasses were moved to air chilling (3°C) for the remainder

of time until fabricated (24 h postmortem, PM). Carcass temperature was continuously recorded (*semimembranosus*, first 24 h PM) and pH was collected (*longissimus lumborum*; 0.5, 1, 2, 4, 6, and 24 h PM). The *longissimus thoracic et lumborum* was excised, cut into chops (2.5 cm thick), and ground while the shoulder was separated and split (Boston butt from picnic shoulder). A chop (5 cm thick) was collected from the caudal side of the Boston butt, and the remainder of the shoulder was boned out, trimmed, and ground. Samples were overwrapped in oxygen-permeable film or vacuum packaged based on their analysis. Color measurements (CIE $L^*$, $a^*$, chemical states of myoglobin) were determined postfabrication (1, 4, 7 d) on meat continuously displayed (1,615 lux). Dependent variables were determined on raw samples (pH; moisture-fat-free [MFF]; expressible moisture; purge; total pigment) and cooked (71°C end-point) samples (Warner-Bratzler shear force [WBS]; thiobarbituric acid reactive substances [TBARS]; hexanal content). The data were statistically analyzed (animal, random effect) for the effects of STUN, CHILL, display time, and their interactions. Week was included as a covariate. In a stepwise manner, nonsignificant ($P > 0.05$) interactions (>2) were eliminated.

Results: ES hogs had a faster ($P < 0.05$) pH decline (0.5 until 6 h PM) compared with $CO_2$, which resulted in ES meat having more ($P < 0.05$) expressible moisture and purge. ES meat was redder (CIE $a^*$) with greater ($P < 0.05$) deoxymyoglobin than $CO_2$. RC resulted in higher ($P < 0.05$) carcass temperatures (4, 6 h PM) compared with CN. RC carcasses had a faster ($P < 0.05$) pH decline (0.5 until 4 h PM) and more expressible moisture and purge compared with CN. RC did not affect ($P > 0.05$) cooler shrink but did impact MFF in that the shoulder had the highest ($P < 0.05$) percentage. RC meat was redder and lighter ($P < 0.05$) in comparison with CN. Metmyoglobin levels were lower ($P < 0.05$) in RC than CN. Regardless of STUN or CHILL, redness decreased and metmyoglobin increased ($P < 0.05$) during display.

Conclusion: Meat quality outcomes may differ depending upon stunning method and carcass chilling method used. Electrical stunning and vascular rinsing can accelerate postmortem glycolysis. Electrical stunning can increase redness in comparison with carbon dioxide stunning. Vascular rinsing can increase redness and has the potential to limit metmyoglobin accumulation during display.

Keywords: carcass vascular rinsing, color, pork, stun method

## 83 SENSORY CHARACTERISTICS OF BEEF TOP SIRLOIN STEAKS PREPARED USING SOUS VIDE AND/OR FLAT-TOP GRILLING METHODS

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Objectives: Hypothesis: Beef top sirloin steaks will have similar palatability traits when sous vide cooked and reheated on a flat-top grill versus those cooked on a flat-top grill only.

Materials and Methods: USDA Choice top sirloin butts ($n = 240$) were aged under refrigeration (0°C to 2°C) for 14, 28, or 35 d ($n = 80$/aging time) and assigned to 1 of 4 treatments: (1) nonblade tenderized, cooked via sous vide (internal temperature of 63°C for 90 min), chilled, and reheated on flat-top grill to internal temperature of 46°C, as commonly used in food service; (2) nonblade tenderized, cooked via sous vide (internal temperature of 58°C for 150 min), chilled, reheated on flat-top grill to internal temperature of 46°C; (3) blade tenderized, cooked on flat-top grill (internal temperature of 70°C); (4) nonblade tenderized, cooked on a flat-top grill (internal temperature of 70°C). Consumer sensory panelists ($n = 224$) were served steaks from a single aging time ($n = 80$ steaks/aging time) over 3 consecutive weeks. Panelists evaluated samples using a 9-point scale (1 = dislike extremely; 9 = like extremely) for overall liking, flavor liking, tenderness liking, and juiciness liking. After the sensory evaluation, panelists were divided into groups to conduct a visual evaluation of exterior and interior appearance of the steaks. After cooking, steaks for WBS force were chilled (2°C to 4°C) for 12 to 16 h, then allowed to equilibrate to room temperature before removing 1.3-cm-diameter cores parallel to the fiber for shear assessment.

Results: Steaks from the sous vide treatment with a lower temperature, longer time, and blade tenderized steaks cooked on a flat-top grill differed ($P < 0.05$) in Warner-Bratzler shear force values at 14 and 35 d age when compared with other cooking treatments. No differences ($P > 0.05$) in consumer panelist ratings for flavor liking and juiciness liking were seen between cooking treatments regardless of aging times. Consumer panelists' scores for tenderness liking were highest ($P < 0.002$) for steaks cooked via sous vide at a lower temperature, and longer time when aged for 14 d. Consumer panelists' visual appraisal scores showed differences ($P < 0.004$) in steaks aged for 28 d. However, no ($P > 0.05$) differences in consumer panelists' visual appraisal scores for steaks aged for 14 or 35 d were found. Additionally, no ($P > 0.05$) differences were identified in consumer panelists' visual ratings for steak presentation or overall liking of interior surfaces.

Conclusion: Tenderness is a leading palatability attribute that drives consumer acceptability of an eating experience. Steaks cooked via sous vide, using a lower temperature, longer time combination, were comparable in tenderness with blade tenderized steaks cooked on a flat-top grill. Top sirloin steaks cooked via sous vide could serve as an alternative preparation method. This could ensure a more consistent product in terms of tenderness and other

attributes on a larger scale destined for foodservice, which would result in more consistent eating experiences by the consumer.

Funding Source: This work was made possible in part by the National Cattlemen's Beef Association.

Keywords: beef, palatability, sous vide, top sirloin steaks, Warner-Bratzler shear force

## 84 THE IMPACT OF FEEDING HEMP BYPRODUCT ON FATTY ACID PROFILE OF MEAT

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Objectives: Hemp byproducts such as hempseed cake might be considered as an alternative protein and fiber source for ruminants. However, hemp cannabinoids (including cannabidiol [CBD] and (-)-$\Delta^9$-tetrahydrocannabinaol [THC]) can have physiologic effects when consumed. CBD is known for anti-inflammatory activity and THC for its psychotropic activity. Yet, hempseed cake with much less than 0.3% THC (dry matter basis) remains an attractive feed alternative. The objective of this study was to evaluate the impact of hempseed cake in a late finishing ration on the fatty acid profile of beef from commercial heifers.

Materials and Methods: Crossbred heifers ($N = 32$) were randomly assigned to 1 of 2 treatments (CON or HEMP) and then to 1 of 4 preslaughter hempseed cake withdrawal periods (day 0, 1, 4, or 8). The CON treatment consisted of corn silage, corn grain, and dried distillers grains with solubles (DDGS). The HEMP treatment replaced DDGS with hempseed cake. The fatty acid data listed as follows include fatty acid concentration levels above 1.00% for total crude fat (CF) and palmitoleic, margaric, stearic, elaidic, oleic, and linoleic acid. The PROC MIXED procedure of SAS 9.4 was used to determine treatment differences across fixed effects (treatment group and withdrawal time) for fatty acid concentration.

Results: No treatment by withdrawal interactions were observed for any fatty acids except for palmitoleic ($P = 0.04$). The significant tendency of myristic should be noted

**Table 1.** Concentration of fatty acids found in beef obtained from crossbred feeder heifers fed a standard finishing diet (CON) vs. a finishing diet containing hempseed (HEMP) withdrawn from diet 0, 1, 4. or 8 days prior to harvest.

| | | Withdrawal Days | | | | | |
|---|---|---|---|---|---|---|---|
| FattyAcids | Trt* | 0 | 1 | 4 | 8 | Trt P Values | Trt × Withdrawal Day Interaction P Value |
| Myristic | CON | 2.63 ± 0.19 | 3.03 ± 0.19 | 2.66 ± 0.19 | 3.14 ± 0.19 | 0.66 | 0.06 |
| | HEMP | 3.21 ± 0.19 | 2.99 ± 0.19 | 2.85 ± 0.19 | 2.65 ± 0.19 | | |
| Palmitic | CON | 23.75 ± 0.86 | 24.86 ± 0.86 | 23.30 ± 0.86 | 24.95 ± 0.86 | 0.45 | 0.24 |
| | HEMP | 25.68 ± 0.86 | 24.05 ± 0.86 | 24.84 ± 0.86 | 24.17 ± 0.86 | | |
| Palmitoleic | CON | 1.32 ± 0.09[a] | 1.27 ± 0.09[a] | 1.15 ± 0.09[a] | 1.56 ± 0.09[b] | 0.74 | 0.04 |
| | HEMP | 1.39 ± 0.09[a] | 1.35 ± 0.09[a] | 1.37 ± 0.09[a] | 1.27 ± 0.09[a] | | |
| Margaric | CON | 1.54 ± 0.09 | 1.59 ± 0.09 | 1.71 ± 0.09 | 1.39 ± 0.09 | 0.26 | 0.28 |
| | HEMP | 1.42 ± 0.09 | 1.52 ± 0.09 | 1.46 ± 0.09 | 1.51 ± 0.09 | | |
| Stearic | CON | 24.64 ± 1.02 | 25.93 ± 1.02 | 26.53 ± 1.02 | 23.67 ± 1.02 | 0.37 | 0.25 |
| | HEMP | 25.08 ± 1.02 | 24.13 ± 1.02 | 24.08 ± 1.02 | 24.84 ± 1.02 | | |
| Elaidic | CON | 4.09 ± 0.33 | 3.93 ± 0.33 | 3.94 ± 0.33 | 3.59 ± 0.33 | 0.19 | 0.32 |
| | HEMP | 3.96 ± 0.33 | 4.60 ± 0.33 | 3.80 ± 0.33 | 4.44 ± 0.33 | | |
| Oleic | CON | 32.94 ± 1.24 | 30.53 ± 1.24 | 31.40 ± 1.24 | 33.02 ± 1.24 | 0.66 | 0.43 |
| | HEMP | 30.59 ± 1.24 | 31.49 ± 1.24 | 32.52 ± 1.24 | 31.72 ± 1.24 | | |
| Linoleic | CON | 2.02 ± 0.21 | 2.21 ± 0.21 | 2.73 ± 0.21 | 2.03 ± 0.21 | 0.002 | 0.18 |
| | HEMP | 1.47 ± 0.21 | 2.01 ± 0.21 | 1.69 ± 0.21 | 1.81 ± 0.21 | | |

*Trt represents treatment; Control (CON) =20% com silage, 55% com grain, 20% DDGS. Hemp (H) = CON diet with replacement of 20% DDGS with 20% hempseed cake.

[1]Values within the same row with different letter indicate significance at ($P < 0.05$).

($P = 0.06$). There was no treatment effect indicated except for linoleic ($P = 0.002$).

Conclusion: The specific level of inclusion of hempseed did not manifest the presence of concentration expected in the muscle.

Funding Source: The project was partially supported by a coordinated agreement between NDSU and the USDA Agricultural Research Service.

Keywords: dried distillers grains with solubles, fatty acids, hempseed

## 85 THE IMPACT OF FEEDING HEMPSEED CAKE TO COMMERCIAL FINISHING HEIFERS ON MEAT QUALITY CHARACTERISTICS

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Objectives: Hemp byproducts can serve as an alternative protein and fiber source for ruminants. However, hemp cannabinoids (cannabidiol [CBD] and (-)-$\Delta^9$-tetrahydrocanabinol [THC]) can have physiological effects after oral exposure. CBD is known for an anti-inflammatory activity and THC for its psychotropic activity, yet hempseed cake with much less than 0.3% THC (dry matter basis) may be a promising feed alternative with precedence in animal ration predating the delegitimization of industrial cannabis in the early 20th century.

The objective of this study was to evaluate the impact of including hempseed cake in a late finishing ration of commercial heifers on meat quality characteristics

Materials and Methods: Crossbred heifers ($N = 32$) were randomly assigned to 1 of 2 treatments (CON or HEMP) and then to 1 of 4 withdrawal periods (day 0, 1, 4, or 8) corresponding to removal of dietary hempseed cake. The CON treatment consisted of corn silage, corn grain, and dried distillers grains with solubles (DDGS). The HEMP treatment replaced DDGS with hempseed cake. Data for pH, purge loss (PL), drip loss (DL), cook loss (CL), and Warner-Bratzler shear force (WBSF) were collected. The PROC MIXED procedure of SAS 9.4 was used to distinguish treatment differences across fixed effects (treatment group and withdrawal time) for pH, PL, DL, CL, and WBSF.

Results: Treatment effects were observed for WBSF ($P = 0.009$), and treatment × withdrawal day interaction indicated significant effect for pH ($P = 0.03$), CL ($P = 0.02$). No differences were measured for PL and DL.

Conclusion: Although treatment and treatment × withdrawal day interaction differences were identified for pH, CL, and WBSF, the conclusion that dietary hempseed cake is the main cause for these effects cannot be easily rationalized.

Funding Source: The project was partially supported by a coordinated agreement between NDSU and the USDA Agricultural Research Service.

Keywords: beef, dried distillers grains with solubles, hempseed cake

## 86 INOSINE-5′-MONOPHOSPHATE TASTE THRESHOLD AND SPIKING EFFECTS ON BEEF FLAVOR

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Objectives: The objective of this study was to determine the taste threshold of inosine-5'-monophosphate (IMP) and the effects of spiking IMP on the sensory descriptive attributes of USDA Standard, Select, Choice, and Prime beef strip steaks.

Materials and Methods: For IMP threshold determination, IMP solutions of 0.045, 0.09, 0.18, 0.36, and 0.72 mM in 0.06% salted water were served in triangle tests (3 replications, 6 to 8 participants) at 15 mL in 30-mL glass containers at 27°C to 32°C. The Best Estimate Threshold (BET) method was used to determine the IMP threshold value. Steaks of USDA Prime (PR), Choice (CH), Select (SE), and Standard (ST) strip loins (NAMP #180; 4 loins per quality grade) were randomly and equally spiked with either 0X, 1X, or 2X within a loin, with "X" being the group threshold value determined after the BET experiment ($n = 16$ per spiking treatment). Steaks were wrapped in aluminum foil, cooked in a convection oven at 177°C until the internal temperature reached 71°C, cut into cubes (1.27 cm × 1.27 cm × 2.54 cm), and served to 8 descriptive sensory panels of 6 to 8 panelists. Descriptive sensory attributes, with a specific focus on umami and bitterness, were evaluated on a 0 (least) to 15 (most intense)-cm line scale. Descriptive data were analyzed as a split-plot design within randomized complete blocks (panels) with USDA quality grade as main factor, loin as main plot, spiking level as split-plot factor, and steak

**Table 1.** LSMEANS (± standard error) for various beef quality parameters obtained from crossbred feeder heifers fed a standard finishing diet (CON) vs. a finishing diet containing hempseed (HEMP) withdrawn from the diet 0, 1, 4, or 8 days prior to harvest.

| | | Withdrawal Days | | | | | |
|---|---|---|---|---|---|---|---|
| Quality Data | Trt | 0 | 1 | 4 | 8 | Trt P Value | Trt × Withdrawal Day Interaction P Value[1] |
| PH | CON | 5.41 ± 0.02[a] | 5.52 ± 0.02[b] | 5.53 ± 0.02[b] | 5.53 ± 0.02[b] | 0.20 | 0.03 |
| | HEMP | 5.49 ± 0.02[b] | 5.52 ± 0.02[b] | 5.52 ± 0.02[b] | 5.52 ± 0.02[b] | | |
| PL (%) | CON | 6.47 ± 0.80 | 6.81 ± 0.80 | 4.94 ± 0.80 | 4.83 ± 0.80 | 0.69 | 0.33 |
| | HEMP | 4.94 ± 0.80 | 7.13 ± 0.80 | 5.74 ± 0.80 | 6.15 ± 0.80 | | |
| DL(%) | CON | 6.07 ± 2.33 | 5.54 ± 2.33 | 4.17 ± 2.33 | 0 ± 2.33 | 0.61 | 0.30 |
| | HEMP | 3.47 ± 2.33 | 1.79 ± 2.33 | 2.50 ± 2.33 | 4.58 ± 2.33 | | |
| CL(%) | CON | 16.11 ± 2.09[a] | 13.30 ± 2.09[a] | 19.37 ± 2.09[ac] | 14.34 ± 2.09[a] | 0.09 | 0.02 |
| | HEMP | 16.96 ± 2.09[a] | 21.07 ± 2.09[b] | 14.34 ± 2.09[a] | 20.97 ± 2.09[bc] | | |
| WBSF (N) | CON | 23.12 ± 2.04 | 16.87 ± 2.04 | 26.53 ± 2.04 | 22.78 ± 2.04 | 0.009 | 0.56 |
| | HEMP | 27.21 ± 2.04 | 20.96 ± 2.04 | 27.63 ± 2.04 | 29.81 ± 2.04 | | |

*Trt represents treatment; Control (CON) = 20% com silage, 55% com grain, 20% DDGS. Hemp (H) = CON diet with replacement of 20% DDGS with 20% hempseed cake.

[1]Values within the same row with different letter indicate significance at ($P < 0.05$).

as split-plot using a general linear model in the GLM procedure of SAS 9.4. The FACTOR procedure of SAS 9.4 was also used to conduct principal component analysis (PCA) of descriptive attributes. Actual probability values were reported.

Results: The individual BET value of umami ranged from 0.032 to 2.02 mM with a group BET value of 0.30 mM. The majority of panelists answered correctly at IMP concentrations of 0.36 mM (56%) and 0.72 mM (75%). There was no interaction ($P > 0.083$) between USDA quality grade and spiking concentration for any sensory descriptive attributes. ST steaks were the least tender ($P < 0.001$) than steaks of other quality grades. Among 2X steaks, CH steaks were juicier than SE ($P = 0.035$) and ST ($P = 0.028$) steaks. Among SE steak, 1X had a more intense flavor ($P = 0.003$) than 0X-SE, whereas CH-2X had more beef flavor than CH-1X ($P = 0.0487$). Among 2X steaks, CH had more beef flavor than SE ($P = 0.003$) and more intense flavor than PR ($P = 0.012$). There was no difference in umami among spiking levels or USDA quality grades ($P > 0.349$); however, umami was in the close proximity to beef flavor and flavor intensity in the PCA biplot (correlation coefficients with PC1 = 0.62, 0.61, and 0.77; $P < 0.001$). There was no difference in bitterness ($P > 0.516$) and off-flavor ($P > 0.370$) across quality grades and spiking levels.

Conclusion: Spiking IMP at threshold levels resulted in no meaningful impact on beef flavor perception. Further analysis of the current data seemed to indicate carryover effects of IMP on umami perception. Such effects may require a smaller number of samples within a session and longer break time between samples. Moreover, umami flavor is difficult to quantify; therefore, further evaluation of umami training and quantification in beef is necessary.

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

Keywords: inosine 5'-monophosphate, sensory, umami, water-soluble flavor compound

## *87 IMPACT OF MUSCLE PH, PACKAGING TYPE, AND POSTCOOKING RESTING TIME ON THE INTERNAL COOKED COLOR BEEF LONGISSIMUS LUMBORUM STEAKS*

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Objectives: Resting steaks following cooking has become an increasingly popular trend among chefs and at-home cooks. However, the impact of resting time on cooked internal color and change in cooked color because of resting steaks has not been studied. Therefore, the objective of this study was to evaluate the cooked internal color of beef strip (*longissimus lumborum*) steaks from USDA Choice and dark colored beef loins subjected to different packaging systems and rest times postcooking.

Materials and Methods: USDA Choice and dark colored strip loins (IMPS #180) with a slightly elevated pH ($n = 6$/loin type) were obtained from a commercial beef processing facility and wet-aged for 14 d under refrigeration. Strip loins were sliced into 2.54-cm steaks beginning from the anterior end of each loin. From each loin, 6 steaks were randomly assigned to 1 of 2 ($n = 2$/packaging type) different packaging systems: high-oxygen modified atmospheric packaging (Hi-Ox MAP; 80% oxygen and 20% carbon dioxide), and vacuum package. Steaks were individually packaged and subjected to 5 d of retail display. Steaks were allowed to sit at room temperature for 25 min prior to cooking on George Foreman grills (Salton, Inc., Columbia, MO). Utilizing handheld thermometers (Thermapen MK4, Thermoworks), the internal temperature of each steak was monitored throughout cooking. Steaks were pulled from grills at an internal temperature of 65°C and then tempered to 71°C. Steaks within each loin, packaging type combination were designated for either a 0-min (unrested) or 7-min rest period once the peak temperature was achieved. At the end of the rest period, steaks were cut parallel to the muscle fiber, and the internal color of each steak was read using a HunterLab MiniScan XE Plus (2.5 cm aperture, Illuminant A, 10° observer angle). The data were averaged across 3 readings, and all data were analyzed using the GLIMMIX procedure of SAS.

Results: A loin pH × packaging × rest time interaction ($P < 0.05$) resulted for $a^*$ values and the ratio of reflectance for 630/580 nm. Steaks packaged in Hi-Ox MAP packaging from both loin types and rest periods had lower ($P < 0.05$) $a^*$ values than all other treatment combinations. Slightly elevated pH steaks in vacuum packaging that were rested for 7 min had a higher ($P < 0.05$) $a^*$ value than the unrested, slightly elevated pH steaks in vacuum packaging. Furthermore, Hi-Ox MAP packaged steaks from both loin types and rest periods had a lower ($P < 0.05$) ratio of 630/580 nm than all other treatment combinations, indicating steaks had a browner internal color and were prematurely brown. Slightly elevated pH steaks that were in vacuum packaging and rested for 7 min had a higher ($P < 0.05$) ratio of 630/580 nm than the unrested slightly elevated pH steak in vacuum packaging, indicating a redder internal color. Also, there was an interaction between the loin pH and rest time for chroma values, in which slightly elevated pH steaks rested for 7 min had a higher ($P < 0.05$) chroma value than unrested slightly elevated pH steaks and Choice steaks rested for 7 min.

Conclusion: The current research indicated that loin color, packaging, and postcooking resting time influence the internal color of steaks. Therefore, understanding these factors that influence cooked meat color will help to further formulate consumer cooking practices.

Keywords: beef, consumer, cooked color, internal color

## *88 THE EFFECT OF INCREASING CARCASS WEIGHT ON PORK CARCASS CHARACTERISTICS AND TRADITIONAL AND ALTERNATIVE FABRICATION YIELDS*

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Objectives: Increasing hot carcass weights (HCW) observed in the pork industry from 1995 and 2018 create the potential to increase revenue from new retail products because individual muscles are heavier when pigs are heavier. In particular, novel cuts through alternative fabrication methods can be created from the shoulder. Therefore, the objective of this study was to characterize the effects of increasing carcass weight on pork carcass characteristics and yields from traditional and alternative fabrication methods.

Materials and Methods: Carcasses ($n = 85$) from pigs slaughtered under university conditions were divided into 3 HCW categories: Light (99 to 109 kg; $n = 30$), Mid (116 to 126 kg; $n = 30$), and Heavy (134 to 144 kg; $n = 25$). HCW, loin muscle area, and back fat depth were measured on all carcasses. Paired left and right sides were fabricated according to either traditional specifications detailed by the North American Meat Processors (NAMP) or alternative specifications. Alternative fabrications included shoulder separation at the 4th/5th rib and generation of a NAMP #406 bone-in Boston butt and a NAMP #405 bone-in picnic. The Boston butt was then fabricated into a cellar-trimmed (CT) butt via removal of the Boston cap from which the supraspinatus and infraspinatus were removed. The *spinalis dorsi* and *serratus ventralis* (SV) were removed from the CT butt. The *teres major* and *triceps brachii* (TB) were removed from the picnic shoulder. All individual primals and subprimals were weighed for yield calculations. Data were analyzed as a one-way ANOVA using the MIXED procedure in SAS with the main effect of weight class and blocked by genotype and sex. Means were considered significantly different at $P \leq 0.05$.

Results: Loin muscle area was increased ($P < 0.01$) in Heavy carcasses (61.4 $cm^2$) compared with Mid carcasses (55.9 $cm^2$). Mid-LMA was increased compared with Light carcasses (50.6 $cm^2$). Conversely, back fat depth ($P < 0.01$) was least in Light carcasses (2.1 cm), followed by Mid (2.5 cm) and Heavy (2.8 cm). Therefore, calculated fat-free lean percentage was decreased ($P = 0.01$) in Mid and Heavy carcasses compared with Light carcasses. Regardless of fabrication method, all whole primals and trimmed subprimals weights increased ($P < 0.01$) in heavier carcass weight classes compared with lighter classes, but often these increases were not maintained when expressed as a percentage of chilled side weight. Novel cut weights from alternative fabrication methods were increased ($P \leq 0.05$) in heavier weight classes compared with lighter weight

classes. SV weight was increased ($P < 0.01$) approximately 0.28 kg from Light to Heavy, whereas CT butt weight was increased ($P < 0.01$) approximately 0.77 kg from Light to Heavy. Additionally, TB weight was increased ($P < 0.01$) approximately 0.25 from Light to Heavy. However, when expressed as a percentage of chilled side weight, there were no differences among SV ($P = 0.64$), CT butt ($P = 0.26$), and TB ($P = 0.83$) between weight classes.

Conclusion: As HCW increased, weights of primals, subprimals, and retail cuts also increased. Additionally, at heavier weights, alternative fabrication of carcasses yielded novel cuts from the shoulder, including the SV and TB, that were of size to warrant further exploration as retail offerings.

Funding Source: National Pork Board.

Keywords: color, fabrication, heavy pigs, hot carcass weight, pork quality

## 89 THE IMPACT OF DIFFERENT PRODUCTION BACKGROUNDS ON MEAT QUALITY AND SENSORY ATTRIBUTES OF HERITAGE AND COMMERCIAL BRED TURKEY

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Objectives: Objectives were to evaluate meat quality attributes of slow-growing heritage turkeys, fast-growing free-range commercial turkeys, and fast-growing conventionally produced commercial turkeys.

Materials and Methods: 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 (−40°C). Prior to fabrication, turkeys were thawed for 96 h in a 2°C to 4°C walk-in cooler. Carcasses within treatments were processed in random order, with CM turkeys processed 1 wk before HB and FR turkeys. Before fabrication, whole carcass weights were obtained, and breast and thigh skin color were measured using a Hunter MiniScan colorimeter. Boneless breast and bone-in thigh weights were obtained, and then the skin was temporarily peeled to measure lean meat color. The thigh was deboned and reweighed, and pH was measured on breast and thighs. Breasts and thighs from the right side were allocated for a trained sensory panel, whereas the left side was used for proximate analysis. Breasts with skin and thighs with skin were individually pulverized in a food processor to form a paste, packaged in Whirl-Pak bags, and frozen (−80°C) until proximate analysis was measured within 3 wk. For sensory analysis, breasts and thighs were vacuum packaged without skin and frozen (−40°C) for 1 mo before thawing at 4°C and then cooked in an 85°C water bath to a peak temperature of 74°C. Samples were analyzed for aroma, juiciness, tenderness, flavor intensity, and off-flavors. Data were analyzed as a split plot design, with type of turkey serving as the whole plot and the part (breast or thigh) serving as the subplot.

Results: An interaction of treatment and part, for pH, was present within HB, CM, and FR breast and thigh meat, with CM thigh having the highest ($P < 0.05$) pH and HB breast having the lowest ($P < 0.05$). All thigh pH, regardless of turkey type, had a higher pH than breast meat. An interaction between turkey type and part showed that fat content of HB and CM thighs was 3% higher than that of FR thighs. There was an interaction for turkey part protein content. The protein contents of breast and thigh meat of FR and HB turkeys were higher ($P < 0.05$) than CM. Breast and thigh meat of HB turkeys was darker ($P < 0.05$) than that of CM and FR, with CM being the lightest ($P < 0.05$). Thigh meat of FR and HB had the highest ($P < 0.05$) redness amount, and CM breast had the lowest ($P < 0.05$) redness values. There were no differences ($P > 0.05$) among breast treatments for overall juiciness, overall tenderness, or off-flavor intensity. Turkey aroma was more intense ($P < 0.05$) for HB than FR or CM regardless of part type. Turkey flavor intensity was the highest ($P < 0.05$) among breasts for HB. For thighs, there were no differences ($P > 0.05$) in off-flavor intensity or turkey flavor intensity. Thigh meat from CM was juicier and more tender ($P < 0.05$) than FR or HB thighs. Although HB thighs had the lowest ($P < 0.05$) overall tenderness, it had the highest ($P > 0.05$) flavor intensity over all parts.

Conclusion: Heritage and free-range turkeys show advantages over commercial turkeys in protein content. Additionally, free-range had the lowest fat content. Differences in meat color were seen between breeds. For breast parts, heritage turkeys had more intense aroma and flavor. Commercial thighs were perceived as juicier and more tender than heritage or free-range thighs.

Keywords: palatability, breast, meat color, thigh, turkey

## 90 INFLUENCE OF FREEZING DURATION AND PACKAGING TYPE ON BEEF PALATABILITY TRAITS

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Objectives: The objective of the study was to evaluate the effect of freezing duration for extended periods on various package and muscle types on slice shear force and expressible moisture (EM).

Materials and Methods: Paired beef strip loins and top sirloin butts were collected from USDA Choice carcasses ($n = 20$). 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 assigned packaging treatments: vacuum packaging (VAC) or aerobic overwrap packaging (OW). Once packaged, the steaks were transported from Canyon, Texas, to Fayetteville, Arizona, to simulate product shipment from a case ready plant to retail. The steaks were then placed in a 3-d simulated retail display and randomly assigned to one of 3 storage treatments: fresh (not frozen), 1-wk freeze, and 1-mo freeze ($n = 64$), with frozen storage being maintained at −20°C. Prior to sliced shear force (SSF), steaks were thawed at 2°C to 4°C and cooked to an internal temperature of 71°C using clamshell grills. A 5-g sample was removed prior to cooking from each steak and placed into a conical tube with glass beads and analyzed for EM. Following cooking, a 1-cm-thick, 5-cm-long slice was removed from each steak parallel to the muscle fibers for SSF evaluation.

Results: There were no differences elicited from the possible interactions for SSF: package × muscle, muscle × duration, package × duration, or package × muscle × duration ($P$ ³ 0.357). However, freezing duration did impact product tenderness ($P < 0.001$). Among treatments, the fresh samples had greater SSF values ($P < 0.05$) than the 1-wk or 1-mo treatments. Similarly, the 1-wk SSF value was less tender ($P < 0.05$) than those analyzed after a 1-mo freezer duration. The SSF was also impacted by the main effect of muscle ($P = 0.022$). The GM possessed greater SSF values ($P < 0.05$) than the LL. The EM was impacted by the package × muscle type interaction ($P = 0.004$). VAC GM steaks possessed the greatest EM values ($P < 0.05$). In contrast, the OW GM steaks had the lowest EM values ($P < 0.05$). Within the OW treatment, the LL samples possessed the greatest EM value ($P < 0.05$). Contrastingly, in the VAC treatment, the GM possessed the greatest EM values ($P < 0.05$). A similar trend existed for the interaction of muscle type and freezing duration ($P = 0.012$). The LL samples that were analyzed as fresh product possessed the lowest EM values ($P < 0.05$). The LL samples that underwent a freezer duration of 1 wk elicited the greatest EM values ($P < 0.05$). Among muscle types, both the 1-wk GM and LM had the highest EM values ($P < 0.05$). Freezing duration also impacted EM as a main effect ($P < 0.0001$). Fresh samples possessed the lowest EM value compared with all other durations ($P < 0.05$). The EM was also influenced by package ($P < 0.0001$). Steaks packaged in VAC possessed greater EM values than OW packages ($P < 0.05$). Muscle also impacted moisture retention ($P = 0.007$). Samples of the GM provided the highest EM values ($P < 0.05$).

Conclusion: These results indicate that freezing duration and muscle type each impact beef tenderness. The muscle type and freezer duration in combination with packaging type has an effect on water retention, which could provide the basis for potential differences observed in product palatability.

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

Keywords: beef, freezing duration, frozen storage, muscle, packaging

## 91 EFFECT OF ANTIMICROBIAL INTERVENTIONS AT AND ABOVE REGULATORY LEVELS ON THE QUALITY OF GROUND BEEF

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Objectives: One of the most important characteristics a consumer takes into consideration when buying meat is its quality, which can be affected by factors such as shelf life, packaging, type of refrigeration, and even antimicrobial interventions that it may have had during processing. Ground beef is very susceptible to microbial contamination and a short shelf life, so it remains a potential source of foodborne illnesses. In the meat industry, a variety of antimicrobial solutions are currently being evaluated that reduce pathogenic microorganisms. To consider these antimicrobial agents as processing aids, the retained water cannot exceed 0.49% addition to product weight. The objective of this study was to determine any influence on product quality in response to antimicrobial treatment at higher uptake percentages.

Materials and Methods: Trim 90/10 and 50/50 (lean to fat ratio) was used to produce ground beef of 3 different lean levels (90/10, 80/20, and 73/37). The trim was weighed in batches of 50 lb prior to intervention (lactic acid 4.5% solution, peracetic acid 400 ppm, or water [control]), which consisted of spray using a multi-purpose sprayer (15 psi with an acceptable spray pattern) for 15 or 40 s to obtain low and high uptake percentages. From each batch, nine 1-lb portions were placed on Styrofoam trays and overwrapped with polyvinyl chloride film. The packages were displayed in a retail case under continuous fluorescent lighting for a total of 4 d. Ground beef was evaluated for instrumental color ($L^*$, $a^*$, and $b^*$), visual color (predominant lean color and percentage of discoloration), and spoilage organisms (aerobic plate count, Enterobacteriaceae, lactic acid bacteria, and psychrotrophic aerobic plate count). The evaluation of ground beef was analyzed within each level using the GLIMMIX procedure of SAS. The evaluation was analyzed within each

lean level. The SLICE function of SAS was used with Day serving as the SLICE option.

Results: Higher fat content ground beef showed higher color $L^*$ values, and all lean levels showed similar mean values for $+a^*$. A significant two-way interaction was observed for $a^*$ between time interval and organic acid for 73/27 and 80/20 ground beef ($P < 0.001$). Mean values for $+a^*$ corresponding to red color decreased at the different sampling points approaching to a green color. A decrease in all color values was observed across time. Discoloration possessed a two-way interaction between time interval and organic acid for 73/27 ground beef ($P < 0.001$). As discoloration increased across time, redness values decreased. Ground beef 90/10 had the highest mean for lean color having the lowest amount of fat. Ground beef evaluated for spoilage organisms displayed a significant difference for all lean levels across time ($P < 0.001$).

Conclusion: The results of this study imply that uptake percentages of up to 1.5% applied to trim with the use of organic acids would not appear to largely impact color and odor of ground beef. Therefore, increased uptake percentages may be utilized for food safety objectives without a need to decrease overall quality or shelf life.

Keywords: characteristic, color, processing aid, spoilage organism

## 92 A COMPARISON OF PROTEIN DEGRADATION AND LIPID OXIDATION BETWEEN FRESH AND FROZEN AMERICAN LAMB

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Objectives: The objective of this study was to evaluate protein degradation and lipid oxidation in 2 muscles (*longissimus lumborum* [LL] and *semimembranosus* [SM]) from fresh and frozen American lamb after 14 d of storage.

Materials and Methods: North Dakota State University raised lambs ($n = 12$) were harvested at the North Dakota State University Meats Lab. After 24-h chill, loin and leg subprimals were collected from each carcass and split in half, and each side was assigned to either fresh (FRSH) or frozen (FRZN) treatments. Subprimals assigned to FRSH were stored at 3°C for 14 d whereas subprimals assigned to FRZN were stored at −18°C for 13 d and at 3°C for 1 d to thaw. For both muscles, a ~5 g sample was collected for troponin-T (TnT) western blotting and lipid oxidation. Samples for drip loss (~25 g), Warner-Bratzler shear force (WBSF), cook loss evaluation (~2.54 cm chop), and sensory evaluation (~2.54 cm chops) were collected. Drip loss, WBSF, and cook loss analyses were conducted in accordance with AMSA guidelines, with chops being cooked to 70°C. Consumer panelists ($n = 84$) were asked to evaluate overall like, flavor, tenderness, and juiciness on a continuous line scale. Meat quality and sensory results were previously reported (Fevold et al., 2021). Immunoreactive bands for TnT were observed at 42, 37–39, 35, 34, 32, and 30 kDa. Lipid oxidation was reported in milligrams of malondialdehyde (MDA) per kilogram of meat. Data were analyzed using PROC MIXED of SAS Studio (SAS Institute, Cary, NC), with means being separated with the PDIFF option, and were considered significant when $P \leq 0.05$. Pearson correlation coefficients were obtained from PROC CORR of SAS Studio.

Results: Treatment did not influence ($P > 0.05$) 42-kDa TnT in the LL. FRZN-LL had greater 37- to 39-kDa ($P = 0.0002$), 35-kDa ($P < 0.0001$) and 34-kDa ($P = 0.0002$) TnT bands compared with those of FRSH-LL. Conversely, FRSH-LL had greater 32-kDa ($P < 0.0001$) and 30-kDa ($P < 0.0001$) TnT bands compared with those of FRZN-LL. FRZN-SM had greater 42-kDa ($P = 0.02$), 37- to 39-kDa ($P < 0.0001$), 35-kDa ($P < 0.0001$), and 34-kDa ($P = 0.01$) TnT bands compared with those of FRSH-LL. Conversely, FRSH-SM had greater 32-kDa ($P = 0.0008$) and 30-kDa ($P < 0.0001$) TnT bands compared with those of FRZN-SM. There was no treatment effect ($P > 0.05$) on MDA levels in either the LL or SM. Drip loss was negatively correlated to the 30-kDa TnT band in both the LL ($r = -0.64$, $P < 0.0001$) and SM ($r = -0.56$, $P < 0.0001$). Treatment did not influence ($P > 0.05$) flavor scores in the LL and SM.

Conclusion: Our results indicate that freezing lamb for 13 d after an initial 24-h chill did not affect lipid oxidation as measured by MDA levels. This conclusion is supported by consumer sensory panel flavor scores, which showed no differences in flavor between treatments. As expected, both FRSH-LL and FRSH-SM had higher abundance of the 30-kDa TnT band than FRZN, indicating more protein degradation in fresh lamb. Previously reported sensory attributes indicated that consumers found FRSH-LL to score higher for like, tenderness, and juiciness, which could be attributed to increased protein degradation. However, the same sensory results were not observed in FRSH-SM, suggesting that greater protein degradation may influence sensory attributes in the LL but not the SM. Thus, lamb legs may be frozen without negative effects on palatability whereas lamb loins should be kept fresh to offer the greatest opportunity for consumer satisfaction.

Funding Source: North Dakota State Board of Agricultural Research and Education.

Keywords: fresh and frozen, lamb quality, lipid oxidation, protein degradation

# Meat and Poultry Quality and Composition - Measurement and Prediction

## 93 COMPARISON OF TWO TYPES OF ELECTRODES USED IN RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY FOR THE ABILITY TO DIFFERENTIATE LAMB FLAVOR PERFORMANCE

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Objectives: Rapid evaporative ionization mass spectrometry (REIMS) is a type of ambient ionization coupled with mass spectrometry detection, enabling real-time evaluation of several complex traits from a single measurement. The I-Knife (monopolar) and Meat Probe (bipolar) are 2 types of ambient ionization sources (electrodes) generating evaporative aerosol for REIMS analysis. The bipolar design of the Meat Probe does not require removing samples from tissue origin for analysis. However, because this is still a beta device, the ability of data generated by Meat Probe to predict meat flavor has not yet been investigated. Therefore, the objective of this study was to compare the data generated by these two electrodes (Meat Probe vs. I-Knife) in their ability to differentiate lamb flavor.

Materials and Methods: Individual lean leg was collected from sheep carcasses ($N = 200$) at 24 h postmortem and made into patties for consumer evaluation and REIMS analysis (Meat Probe and I-Knife). Every sample was evaluated by 6 consumers. REIMS analysis of the raw lamb was performed by the 2 electrodes, and the resulting data were used to develop multivariate models to predict and classify cooked lamb flavor acceptance (intensity level, intensity acceptance, flavor acceptance, off-flavors presence, and overall acceptance) based on consumer response and carcass background (age, diet, and gender). REIMS data were pre-processed by 2 types of dimension-reduction methods and then evaluated by 15 machine learning algorithms to predict each classification by leave-one-out cross validation in R. Maximal prediction accuracies of each classification and analysis speed were compared between Meat Probe and I-Knife REIMS analysis.

Results: The maximal prediction accuracies from models based on data generated by I-Knife REIMS analysis for each classification were as follows: age (72%), diet (92%), gender (73%), intensity level (73%), intensity acceptances (84.5%), flavor acceptance (81.5%), off-flavors presence (78%), and overall acceptance (84%). The maximal prediction accuracies from models based on data generated by Meat Probe REIMS analysis for each classification were as follows: age (81.5%), diet (90%), gender (72.5%), intensity level (68%), intensity acceptances (86%), flavor acceptance (80%), off-flavors presence (77.5%), and overall acceptance (85%). Analysis using the Meat Probe required 45 s per sample (5 readings), whereas analysis using the I-Knife required 90 s per sample (5 readings).

Conclusion: Data generated using the Meat Probe resulted in models with better or similar prediction accuracies of carcass background (age, diet, and gender) and consumer preference (intensity acceptance, flavor acceptance, off-flavors presence, and overall acceptance) as compared with models based on data generated using the I-Knife. The Meat Probe was more user-friendly, faster, and cleaner than I-Knife for REIMS analysis. Further investigations are necessary to evaluate the use of the Meat Probe for REIMS analysis in other applications.

Funding Source: Funding was provided by the American Lamb Board.

Keywords: consumer preference, cross validation, I-Knife, Meat Probe, rapid evaporative ionization mass spectrometry

## 94 A HISTORICAL ANALYSIS OF CARCASS DATA COLLECTED 1992–2021 BY THE WEST TEXAS A&M UNIVERSITY BEEF CARCASS RESEARCH CENTER

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Objectives: The Beef Carcass Research Center database ($N = 1{,}064{,}609$) generated from 1992 to 2021 was used to identify carcass outcomes, trends, and associations.

Materials and Methods: Carcass data was collected at 43 federally inspected beef abattoirs in the United States and Canada. Outcomes included hot carcass weight (HCW), loin muscle area (LMA), adjusted 12th rib fat thickness (AFT), calculated yield grade (YG), LMA to HCW ratio (RATIO), marbling score (MARB), hair coat color, and sex.

Results: Mean carcass outcomes were as follows: YG (2.85), AFT (1.3 cm), HCW (369.7 kg), LMA (87.0 $cm^2$), KPH (2.1%), RATIO (0.2445 $cm^2$/kg), and MARB (Small[23]). Regression equations were calculated to determine change in carcass outcomes over time. Mean HCW, LMA, YG, and AFT increased linearly by 2.39 kg, 0.42 $cm^2$, 0.00639 units, and 0.12 cm while RATIO decreased in a linear manner by 0.0002 $cm^2$/kg, whereas MARB increased in a quadratic manner. Based on these annual trends, predicted

values for carcass outcomes at the year 2050 are as follows: HCW (473.6 kg), LMA (106.7 $cm^2$), AFT (1.8 cm), MARB (Modest[30]), YG (3.15), and RATIO (0.2397 $cm^2$/kg). These data illustrate strong association ($P < 0.01$) between YG and carcass outcomes. As YG increased by 1 unit (i.e., YG 2.0 to 3.0), AFT, HCW, and MARB increased ($P < 0.01$) by 0.5 cm, 14.6 kg, and 3.9 units, whereas LMA and RATIO decreased ($P < 0.01$) by 7.2 $cm^2$ and 0.0304 $cm^2$/kg. Hot carcass weight groups were also influential ($P < 0.01$) upon carcass outcomes. As HCW increased by 100 kg, YG, AFT, LMA, and MARB increased ($P < 0.01$) by 0.51 units, 0.3 cm, 12.6 $cm^2$, and 3.1 units, whereas RATIO decreased by 0.0340 $cm^2$/kg. Similarly, as AFT increased by 0.254 cm, YG, HCW and MARB increased ($P < 0.01$) by 0.33 units, 5.6 kg, and 1.6 units, whereas LMA and RATIO decreased by 0.54 $cm^2$ and 0.0054 $cm^2$/kg. Quality grade was also strongly associated ($P < 0.01$) with carcass outcomes; as quality increased from Select to Choice, YG (+ 0.38 units), AFT (+ 0.22 cm), and HCW (+ 8.8 kg) increased ($P < 0.01$), while LMA (−1.5 $cm^2$) and RATIO (−0.0105 $cm^2$/kg) decreased. Likewise, as quality grade increased from Choice to Prime, YG (+ 0.5), AFT (+ 0.34 cm), and HCW (+ 7.6 kg) increased ($P < 0.01$), whereas LMA (−1.24 $cm^2$) and RATIO (−0.0082 $cm^2$/kg) decreased. Steers exhibited greater ($P < 0.01$) YG (+ 0.07), and HCW (+ 26.5 kg) and less ($P < 0.01$) LMA (−0.46 $cm^2$), AFT (−0.2 cm), MARB (−2.2 units), and RATIO (−0.0194 $cm^2$/kg) than heifers. The effect of railout status was assessed; carcasses that had been railed off-line for enhanced trimming exhibited lesser ($P < 0.01$) YG (−0.19), AFT (−0.12 cm), LMA (−2.47 $cm^2$), and MARB (−2.13 units) and dramatically lighter HCW (−18.23 kg) but increased RATIO (+ 0.0074 $cm^2$/kg) compared with non-railout carcasses. Probability of carcasses grading Choice (CH), Premium Choice (PrCH), or Prime (P) was calculated. As HCW increased from 400 to 500 kg, the probability of grading CH, PrCH, or P increased by 12%, 9%, and 1.5%, respectively. Likewise, as AFT increased from 1.5 to 2.5 cm, an increase of 21.9%, 23.9%, and 4.2% occurred in the probability of grading CH, PrCH, and P. In contrast, as LMA increased from 90 to 100 $cm^2$, a decrease of 3.5%, 1.8%, and 0.20% occurred in the probability of grading CH, PrCH, and P.

Conclusion: These data serve as excellent indicators of the future of beef production to be used by beef producers and processors.

Keywords: beef carcass, carcass characteristics, fat thickness, ribeye area, yield

## 95 LIPID PROFILE IN GROUND BEEF COMPARED WITH PLANT-BASED PROTEIN ALTERNATIVES

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Objectives: In recent years, there has been increased popularity in plant-based protein alternatives as consumers become more concerned with their health and the environment. The objective of this study was to compare the lipid profile in ground beef and plant-based protein products available to consumers in the United States.

Materials and Methods: The Impossible Burger (IMP), Beyond Burger (BB), a third available brand of plant-based protein (GEN), 85/15 ground beef (85:15), and 97/3 (97:3) ground beef were collected from local and national chain grocery stores in 6 cities within the eastern, western, and central regions of the United States. Six packages were collected from at least 2 stores in each city, then shipped to Texas Tech University. Once samples arrived at Texas Tech University, overwrap and modified atmosphere packages were opened, weighed into 150 g portions, formed into patties, and vacuum sealed. Samples were homogenized, then stored at −80°C for further analyses. Total lipid content was measured using a chloroform-methanol extraction. Additionally, fatty acid methyl esters were analyzed using a gas chromatograph fixed with a flame-ionization-detector. Fatty acids were calculated and quantified on a mg/g basis. Saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) percentages were calculated from the total fatty acid content. Data were analyzed as randomized complete block design with 6 blocks representing the collection city and 36 replications per 5 product types. An alpha of $P \leq 0.05$ was used to determine significance.

Results: Total lipid content, SFA, MUFA, and PUFA were influenced by product type ($P < 0.001$). Total lipid content was highest in 85:15, followed by GEN and BB ($P < 0.05$). 97:3 had the lowest total lipid content ($P < 0.05$). Interestingly, IMP had the highest percentage of SFA (55.11%), followed by 85:15 (44.72%) and 97:3 (46.84%) ($P < 0.05$). IMP had the greatest myristic acid content, which contributed to IMP having the highest percentage of SFA relative to the total fatty acid content. Additionally, 85:15 had the highest percentage of MUFA (51.66%), while BB and IMP had the lowest ($P < 0.05$). However, BB had the highest percentage of PUFA (15.73%) whereas 85:15 had the lowest at 3.62% ($P < 0.05$). Linoleic acid content was greatest in BB, which increased the percentage of PUFA in the product ($P < 0.05$). Content of palmitic acid, oleic acid, and stearic acid was greatest in 85:15 ($P < 0.05$).

Conclusion: The fatty acid composition in ground beef products and plant-based protein products varied in total lipid content, SFA, MUFA, and PUFA. Fatty acids known to be high in beef such as palmitic, oleic, and stearic acids, were greatest in 85/15 ground beef. The IMP was the most like 85/15 ground beef in SFA and PUFA. Varying fatty acid composition can influence the nutritive value of foods as well as overall quality, so this should be considered during product formulation.

Funding Source: The Beef Checkoff contracted by the National Cattleman's Beef Association.

Keywords: beef, fat content, fatty acids, ground beef, plant-based

## 96 PREDICTING ANIMAL IDENTITY AND AGE OF LONGISSIMUS LUMBORUM STEAKS USING RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY (REIMS)

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Objectives: The meat industry could benefit from a technology with the capability of tracking meat products back to an individual animal. Rapid evaporative ionization mass spectrometry (REIMS) is a novel technology that utilizes metabolomics to identify compositional differences and classify samples. The objectives of this study were to (1) evaluate the ability of REIMS to classify product age and (2) determine the animal origin of beef striploin steaks.

Materials and Methods: Paired striploins ($N = 84$) were selected from carcasses of 2 quality grades (USDA Select and upper two thirds Choice) and collected at a commercial harvest facility during fabrication (approximately 36 h postmortem). All strip loins were transported to Texas Tech University and fabricated into 6 cm sections ($N = 499$). Sections were assigned to one of 6 aging treatments (3, 14, 28, 42, 56, or 70 d) and wet aged at 3.5°C, in a dark environment. Upon completion of an aging interval, chunks were individually frozen and held at −20°C. Once all samples had completed aging, samples from the same carcass were randomly assigned to a day for REIMS analysis. Samples were thawed at 4°C for 12 to 18 h prior to analysis. Spectra were collected from samples using a Synapt G2-Si Q-TOF equipped with a REIMS source and an iKnife sampling device in negative resolution mode. Data were preprocessed using AMX, and all statistical analyses were completed in Rstudio. Principal component analysis (PCA) was conducted to create new variables (principal components) by combining variables based on covariance values. The feature selection (FS) technique, recursive feature elimination (RFE), was used on REIMS bin data, and principal components to create 2 new data sets (FS; PCA-FS). These data sets were used in combination with 13 machine learning techniques and a 10-fold cross validation to build and test models. Finally, the top 3 age models were further investigated using a leave-one-out cross-validation technique.

Results: RFE selected 7 REIMS bins (FS) and 82 principal components (PCA-FS) as the primary drivers of difference between the aged striploin chunks. All models built with FS data performed with higher accuracy then those built with PCA-FS data. The highest levels of accuracy for age prediction were obtained using FS data combined with the elastic-net regularized generalized linear model (GLMnet; 49.3%), linear discriminant analysis (LDA, 48.5%), and the support vector machine with polynomial kernel (SVMpoly; 48.1%). These models were explored using the leave-one-out cross-validation technique in which the top accuracy was achieved with the SVMpoly model (48.1%). When accuracy parameters were expanded to account for an error of one class (2 wk), an accuracy of 94.0%, was computed from the FS data in an LDA model. RFE selected 225 REIMS bins (FS) and 196 principal components (PCA-FS) to predict carcass identity. Top accuracies were achieved using the PCA-FS data set in combination with penalized discriminant analysis (99.2%) and LDA (99.2%) models, as well as the FS data set using a penalized discriminant analysis model (98.7%).

Conclusion: Overall, REIMS displayed an ability to classify samples based off metabolomic differences resulting from both age and animal identity with high levels of accuracy. Further research into these abilities could result in potential applications for product traceability.

Funding Source: United States Department of Agriculture/Agriculture and Food Research Initiative–Foundational and Applied Science.

Keywords: beef, machine learning, mass spectrometry, metabolomics, rapid evaporative ionization mass spectrometry

## 97 IMPROVEST IMPROVES UNIFORMITY OF CARCASS WEIGHT AND OPTIMIZES BACK FAT THICKNESS IN MARKET GILTS

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Objectives: Improvest is a gonadotropin releasing factor (GnRF) analogue-diphtheria toxoid conjugate injection approved for the temporary suppression of ovarian function and estrus in market gilts (Zoetis Canada Inc.). The objective of this study was to assess the mean differences and distribution of carcass weight and optical probe readings (back fat thickness, muscle depth, and predicted lean yield) of Improvest gilts (IMP gilts) compared with untreated gilts (UNT gilts) and physically castrated barrows (PC barrows).

Materials and Methods: A total of 924 pigs were raised in 3 rooms of a commercial finishing barn in Central Manitoba. Within each room there were 14 mixed-sex pens with 22 pigs per pen. Within each pen, there were an equal number of gilts and barrows. Half of the gilts in each pen were randomly selected to be treated with a GnRF analogue injection (Improvest; IMP gilts), and the other half were not treated with the GnRF analogue injection (UNT gilts). At the completion of the finishing period, all pigs in each room were marketed over a 28-d period with equal proportions of each treatment marketed on each day (a ratio of 1:1:2 for IMP gilts, UNT gilts, and PC barrows, respectively). Pigs were humanely slaughtered at a pork processing plant using industry protocols. Hot carcass weight and optical probe readings (Destron PG-203; Anitech Identification System Inc.) were collected during slaughter. Carcass served as the experimental unit for all analyses. Data were analyzed as a general linear mixed model with PROC MIXED of SAS using a fixed effect of sex and random effects of room, slaughter day, and their interactions with sex. Least-squares means were separated using the PDIFF option of SAS with a Tukey-Kramer adjustment. Distributions for each parameter were created in Microsoft Excel.

Results: The time between the second Improvest injection and marketing (i.e., the period of time in which temporary suppression of ovarian function and estrus occurred) was 36.2 ± 7.7 d. Hot carcass weight was greater ($P \leq 0.02$) and standard deviation was improved in IMP gilts (98.2 ± 5.1 kg) and PC barrows (99.2 ± 4.4 kg) when compared with UNT gilts (95.8 ± 6.6 kg). Back fat thickness was greater ($P < 0.01$) in IMP gilts (17.1 ± 3.4 mm) and PC barrows (18.1 ± 4.4 mm) when compared with UNT gilts (14.8 ± 3.4 mm). Muscle depth was greater ($P = 0.02$) in IMP gilts (63.0 ± 6.7 mm) when compared with PC barrows (61.2 ± 6.7 mm), whereas UNT gilts (62.0 ± 7.3 mm) were intermediate and not different than IMP gilts or PC barrows. Predicted lean yield was greater ($P < 0.01$) in UNT gilts (62.5% ± 1.8%) compared with PC barrows (60.9% ± 1.9%), whereas IMP gilts (61.3% ± 1.6%) were intermediate and not different than UNT gilts or PC barrows.

Conclusion: Hot carcass weight and back fat thickness for IMP gilts were intermediate in their mean values when compared with PC barrows and UNT gilts, suggesting that the gap in carcass uniformity between barrows and gilts can be narrowed when gilts are treated with Improvest. Furthermore, the standard deviation for hot carcass weight was improved by 22.7% in IMP gilts (standard deviation = 5.1 kg) when compared with UNT gilts (standard deviation = 6.6 kg). This reduction in standard deviation observed when Improvest was used in market gilts should increase premiums for producers selling pigs on a grid-based marketing system and improve system efficiencies for pork processors.

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Keywords: carcass characteristics, immunological suppression of estrus, Improvest, market gilts

## 98 FREEZING IMPROVES MEAT TENDERNESS BY ENHANCING POSTMORTEM PROTEOLYSIS

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Objectives: Fresh meat is vulnerable to microbial contamination and loss of quality. Hence, freezing is used to mitigate these issues during the transport and storage of muscle foods. However, the degree to which ice crystals form during the freezing period has been shown to impact meat quality characteristics, especially tenderness. The formation of large ice crystals can improve tenderness through mechanically damaging myofibrillar structures. In addition, ice crystals may disrupt key cellular organelles such as the sarcoplasmic reticulum and mitochondria. This, in turn, could impact the proteolytic activity of calpain-1, the main protease responsible for postmortem proteolysis. Indeed, improved proteolysis has been previously observed after freezing/thawing of meat. However, to the best of our knowledge, no previous studies have thoroughly investigated calpain-1 activity following the freezing of meat. Therefore, the aim of this research was to evaluate the impact of

**Table 1.** Effects of a gonadotropin releasing factor (GnRF) analogue diphtheria toxoid conjugate injection (Improvest) on carcass characteristics of market gilts (L5 Means ± Standard Deviation).

| | Treatments[1] | | | *P*-values | |
|---|---|---|---|---|---|
| Parameter | PC Barrows | UNT Gilts | IMP Gilts | IMP Gilts versus PC Barrows | IMP Gilts versus UNT Gilts |
| Hot carcass weight, kg | 99.2 ± 4.4 | 95.8 ± 6.6 | 98.2 ± 5.1 | 0.20 | 0.02 |
| Back fat thickness, mm | 18.1 ± 4.4 | 14.8 ± 3.4 | 17.1 ± 3.4 | 0.08 | < 0.01 |
| Muscle depth, mm | 61.2 ± 6.7 | 62.0 ± 7.3 | 63.0 ± 6.7 | 0.02 | 0.41 |
| Predicted lean yield, % | 60.9 ± 1.9 | 62.5 ± 1.8 | 61.3 ± 1.6 | 0.09 | < 0.01 |

[1]PC Barrows: physically castrated barrows, UNT Gilts: gilts not receiving the GnRF analogue injection, and IMP Gilts: gilts receiving the GnRF analogue injection (Improvest).

freezing/thawing on beef tenderness and the extent of proteolysis. We hypothesized that freezing/thawing improves calpain-1 activity through disrupting the sarcoplasmic reticulum and mitochondria, and subsequently increasing cytosolic calcium concentration.

Materials and Methods: Eight steers were harvested, and the *longissimus thoracis et lumborum* muscle was collected from one side of all carcasses 24 h postmortem. Each muscle was fabricated into eight 2.5-cm-thick steaks. Steaks were individually vacuum packaged and randomly divided into 4 experimental groups (2 steaks per group). The first group of steaks was aged for 24 h, whereas the second group was aged for 168 h at 4°C. The third and fourth groups were frozen for 24 h at −20°C and subsequently aged for 24 or 168 h at 4°C, respectively. At the end of each aging period, one steak from each group was cooked and used for Warner-Bratzler shear force (WBSF). The second steak was used for determining thaw loss, drip loss, mitochondrial oxygen consumption rate, calpain-1 autolysis, and the extent of proteolysis. Data were analyzed using Tukey-Kramer multiple comparisons test, with $P \leq 0.05$ considered significant.

Results: Our results indicated that frozen/thawed steaks had lower WBSF values than the control ($P < 0.05$) at 24 and 168 h. Additionally, treated steaks possessed greater drip and thaw loss values ($P < 0.05$). An improvement in calpain-1 autolysis and desmin degradation ($P < 0.05$) was observed in the frozen/thawed steaks at both 24 and 168 h. On the other hand, mitochondrial respiration rate was lower ($P < 0.05$) in the frozen/thawed steaks at 24 h, indicating greater mitochondrial dysfunction.

Conclusion: Collectively, our data demonstrate that proteolysis and tenderness in beef were improved after freezing/thawing, whereas water-holding capacity was impaired. The improvement in tenderness is likely a function of increased calpain-1 autolysis through increasing cytosolic calcium levels due to mitochondrial and sarcoplasmic reticulum dysfunction.

Keywords: freezing, mitochondria, proteolysis, tenderness

## 99 ABILITY OF RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY TO PREDICT BEEF TENDERNESS, JUICINESS, AND FLAVOR

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Objectives: Non-destructive techniques that can predict beef palatability traits (flavor, tenderness, and juiciness) in real time could improve beef marketability. Rapid Evaporative Ionization Mass-Spectrometry (REIMS) is an ambient mass spectrometry technique that provides rapid chemometric profiling of biological tissues *in situ*, without sample preparation. The goal of this study was to evaluate the ability of REIMS as a real-time method to predict beef sensory attributes.

Materials and Methods: USDA Select or upper two-thirds Choice ($n = 42$, $N = 84$) strip loins were collected approximately 36 h postmortem from a commercial beef abattoir. In addition, slivers of the *longissimus dorsi* muscle between the 12th and 13th rib were collected at the grading time and used to obtain mass spectra profilings with REIMS. Striploins were cut into 6 cm portions and assigned to 3 aging periods (3, 14, or 28 d). After aging, portions were cut into 2.54 cm steaks to analyze juiciness, tenderness, and 12 flavor attributes with a trained sensory panel. In addition, tenderness measures were performed using slice shear force (SSF) and Warner-Bratzler shear force (WBF). Samples were categorized by SSF, WBF, and sensory panel tenderness (PT) into "tough" and "tender"; by juiciness into "dry" and "juicy"; and by flavor into "acceptable" and "unacceptable" classes using a composite score of all flavor descriptors. Partial least squares discriminant analysis (PLS-DA) was used to analyze REIMS data across classes. Combinations of 3 dimensionality reduction methods (principal component analysis, PCA; feature selection, FS; and a combination of both PCA-FS) with 13 machine learning algorithms were used to create classification models based on REIMS data for tenderness, juiciness, and flavor classes at the 3 aging periods. The predictive ability of the models was assessed with the overall accuracy resulting from 10-fold cross-validation.

Results: All PLS-DA plots showed overlap between classes. However, REIMS still showed the ability to segregate samples for all the attributes. From all machine learning algorithms evaluated the maximum classification accuracies for days 3, 14, and 28 were 94%, 87%, and 83% for PT; 86%, 85%, 92% for SSF; 87%, 82%, and 95% for WBF; 85%, 84%, and 86% for juiciness; and 87%, 89%, and 81% for flavor classes, respectively. FS performed the best as a dimensionality reduction method for all PT, juiciness, flavor, and SSF on day 3, and WBF on days 3 and 14. On the other hand, PCA-FS was the best method for SSF on days 14 and 28, and WBF on day 28. Extreme gradient boosting machine learning algorithm was the highest performing for all juiciness models, flavor model on day 28, PT on days 3 and 14, SSF on days 14 and 28, and WBF on days 3. PLS-DA performed better for PT day 28 and flavor day 14, while elastic-net regularized generalized linear model, random forest, and support vector machine were the highest performing algorithms for SSD day 3, WBF day 14, and WBF day 28, respectively.

Conclusion: Results demonstrated that the chemical fingerprints obtained with REIMS could potentially be used as *in situ* and real-time technique to sort carcasses by flavor, juiciness, and tenderness. Overlaps between classes affected REIMS predictive ability resulting in lower accuracy; therefore, increasing the sample size or gap between sensory classes could increase the accuracy of the models.

Funding Source: United States Department of Agriculture/ Agriculture and Food Research Initiative - Foundational and Applied Science.

Keywords: rapid evaporative ionization mass spectrometry, beef flavor, tenderness, juiciness

## 100 DETERMINATION OF CONSUMER COLOR AND DISCOLORATION THRESHOLDS FOR PURCHASE OF RETAIL GROUND BEEF WHEN EVALUATING MULTIPLE DAYS OF DISPLAY SIMULTANEOUSLY

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Objectives: The objective of this study was to identify the threshold for color and discoloration for consumers to purchase ground beef in a simulated retail display and determine the best objective measurement to predict consumer purchase intent.

Materials and Methods: For this study, 180 to 454 g 80/20 ground beef packages were obtained from a commercial processor in Kansas and transported to the Kansas State University Meat Laboratory. Packages were assigned to day of retail display (day 0 to day 9). Ground beef packages from each day of display were displayed in coffin-style cases under fluorescent lights. Consumers ($n = 216$) evaluated ground beef samples from each day of display simultaneously. Consumers were asked to assess the overall appearance and desirability of each of sample on 100-point continuous lines scale. Additionally, consumers answered yes/no questions related to whether they would purchase the package if it was full-priced at retail, and if it was discounted at retail. A trained descriptive panel evaluated the samples for redness and percentage discoloration using 100-point continuous line scales. $L^*$, $a^*$, and $b^*$ values were collected utilizing a Hunter Lab Miniscan spectrophotometer, and spectral data were recorded for the calculation of hue angle, chroma, percentage oxymyoglobin, and percentage metmyoglobin. Logistic regression models were calculated for the probability of a sample being identified as "would purchase" for both full-price and discounted responses by consumer sensory panelists. Simple linear regressions were calculated for consumer overall appearance ratings. Pearson correlation coefficients were calculated for sensory and objective measurements.

Results: Overall, our models showed that each of the objective measures evaluated were satisfactory predictors of consumer purchasing intent. All logistic regression equations ($P < 0.01$) had high $R^2$ values of 0.48 to 0.86 and correctly classified 78.1% to 90.1% of samples as would/would not purchase. Linear regression equations predicting consumer overall appearance ratings with objective measures also resulted in significant ($P < 0.01$) models, with $R^2$ values of 0.57 to 0.93. Pearson correlation coefficients showed strong relationships ($P < 0.01$) between consumer appearance score and all other variables ($r > 0.92$), except for $L^*$ ($r = 0.76$). The $a^*$ values of 21.6, 24.6, 28.3, and 30.5 correspond with consumers being 50%, 75%, 90%, and 95% likely to purchase the product at full price. However, if the product was discounted, these numbers were 17.9, 21.4, 25.0, and 27.4. The percentage of metmyoglobin values of 40.1, 33.6, 27.1, and 22.7 correspond with consumers being 50%, 75%, 90%, and 95% likely to purchase the product at full price. However, if the product was discounted, these numbers shifted substantially to 47.8, 40.5, 33.2, and 28.2.

Conclusion: All objective measurements were satisfactory predictors of consumer purchasing intent of 80/20 ground beef. Objective measurements shown to be the best included $a^*$ value and calculated percentage metmyoglobin. The models generated from this study provide the ability to predict consumer willingness to purchase ground beef of varying days of retail display and provide ground beef producers an indication of potential consumer purchasing behaviors based upon objective measures that are easy to measure.

Keywords: color, consumer, metmyoglobin, oxymyoglobin, sensory

## 101 DETERMINATION OF CONSUMER COLOR AND DISCOLORATION THRESHOLDS FOR PURCHASE OF RETAIL GROUND BEEF WHEN EVALUATING PACKAGES OF A SINGLE DAY OF DISPLAY

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Objectives: This study utilized a simulated retail display to investigate the impact of ground beef color and discoloration

on consumer purchase intent, while identifying the best objective measurements to predict consumer preferences of ground beef on the same day of retail display.

Materials and Methods: A commercial processor provided 180 to 454 g 80/20 ground beef loaves for this study. Each loaf was assigned to a specific day of retail display (day 0 to day 9) and placed under fluorescent lights in coffin-style cases. Consumers ($n = 318$) assessed ground beef samples at each day of display, with a single day of display evaluated per consumer group. Consumers used 100-point continuous line scales to indicate overall appearance for each sample and indicated their willingness to purchase the loaves at full price and discounted prices with yes/no questions. A trained descriptive panel assessed redness and percentage discoloration values. A HunterLab Miniscan spectrophotometer collected $L^*$, $a^*$, and $b^*$ values, and hue angle, chroma, percentage oxymyoglobin, and percentage metmyoglobin were calculated. Simple linear regressions were calculated for consumer overall appearance ratings, while logistic regression models were calculated for the probability of each sample being classified as "would purchase" for full price and discounted responses from consumers. Lastly, Pearson correlation coefficients were calculated for relationships among sensory and objective measurements.

Results: Results of these models showed that the objective measurements assessed were accurate indicators of consumer purchase intent. Linear regression equations that predicted consumer overall liking of appearance scores were significant ($P < 0.01$), with $R^2$ values of 0.35 to 0.54. Logistic regression equations that predicted consumer purchase intent were also significant ($P < 0.01$) for all objective measures and had $R^2$ values of 0.26 to 0.65. The logistic regression models accurately classified 70.5% to 84.0% of samples as would/would not purchase. Reported Pearson correlation coefficients were significant ($P < 0.01$) among all variables with $r$ values of 0.10 to 0.99. Threshold values for consumer willingness to purchase for chroma were 29.7, 35.5, 41.3, and 45.2, which aligned with consumers being 50%, 75%, 90%, and 95% likely to purchase the ground beef at full price, whereas packages sold at a discounted price saw reduced chroma values to 25.8, 30.8, 35.8 and 39.2, respectively. Notably, thresholds for trained sensory panel discoloration scores (a measure of surface browning) were 40.3 and 12.8, which coincided with consumers being 50% and 75% likely to purchase ground beef at full price. These scores shifted to 79.0 and 42.4 for discounted packages, indicating consumer willingness to purchase ground beef with greater discoloration when offered at a lower price.

Conclusion: Consumer intent to purchase ground beef at varying days of retail display can be predicted by the objective measures used in this study. Several measures, including chroma, $a^*$, metmyoglobin content, and trained sensory panel discoloration scores, were good predictors of consumer likelihood to purchase. Moving forward, these models can provide ground beef producers and retailers an indication of potential consumer purchasing behaviors for ground beef at varying levels of discoloration.

Keywords: $a^*$, color, consumer, ground beef, sensory

## 102 IMPACT OF BLOOM TIME ON RIBEYE COLOR, RIBEYE AREA, MARBLING SCORE, AND YIELD GRADE USING SMARTCAM BEEF CARCASS GRADING TECHNOLOGY

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Objectives: Implementation of grading cameras in beef packing plants to calculate and establish yield and quality grades is well established; however, as the technology evolves, maintaining the accuracy of the data it captures is critical. The changes meat naturally undergoes during post-ribbing bloom time and how long post-ribbing that data are captured may have an effect on instrument traits used to determine carcass grade traits. The SmartCam grading instrument based on cell phone technology was developed to create a portable grading camera for off-line applications. It is important to determine the robustness of this technology across the diversity of situations in which the camera may be applied to carcasses in small- and medium-sized plants that rib and grade carcasses on static rails or regrade applications. This study evaluated the impact of collecting SmartCam data through 3 post-ribbing stages with variable bloom times on ribeye color, ribeye area, marbling score, and yield grade.

Materials and Methods: The SmartCam was used to capture 3 different images of the same side of 72 beef carcasses at the ribbing chain, bloom chain, and grading chain. The camera was operated through multiple groups of carcasses to help maintain carcass identification through all 3 data collection points. The same side of each carcass was captured on the ribbing, bloom, and grading chains at approximately 30 s, 9 min and 30 s, and 17 min and 30 s after ribbing, respectively. Data were analyzed using PROC VARCOMP of SAS to evaluate the repeatability of camera assessments and to access the proportion variance attributable to variation among carcasses, bloom time, and error. Additionally, PROC GLIMMIX of SAS with a fixed effect of evaluation time (ribbing, bloom, or grading chain) and a random effect of carcass ID were used 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 >99%,

<0.2%, and <0.8% of the total variance, respectively. The mixed model showed that marbling score was higher on the ribbing (597; Modest97) chain than the bloom (588) and grading (587) chains ($P < 0.0001$). SmartCam ribeye lean color assessment showed the variable RibeyeColor_r, which is the red channel on the RGB color scale, increased 8.8 units from the ribbing chain (79.9) to the bloom chain (88.7) and RibeyeColor_r increased an additional 3.9 units between the bloom chain and the grading chain (92.6; $P < 0.0001$ for each comparison). SmartCam RibeyeColor_r repeatability was > 0.99 with carcass ID, bloom time, and error accounting for 63%, 36%, and <1% of the total variance, respectively. Bloom time did not affect SmartCam yield grade.

Conclusion: Follow-up studies should include changes in times between ribbing chain, bloom chain, and grading chain to observe effects on a more accurate bloom time. Methods to enhance accuracy and precision of ribeye color, marbling score, ribeye area, and yield grade will increase the use of SmartCam technology on a wide scale.

Funding Source: USDA and Texas Tech University.

Keywords: beef grading, bloom time, ribeye color, technology

## 103 FRESH PORK LOIN LIPID DETERMINATION USING CEM ORACLE AND SOXHLET METHODOLOGY

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Objectives: Pork quality impacts the demand for and value of fresh pork in today's global marketplace. Pork composition, specifically lipid content, is often associated with pork loin quality. Therefore, there is utility in having access to rapid and reliable methods to analyze pork loin composition. The Soxhlet and CEM Oracle methods are AOAC-approved methods for determining the neutral lipid content of foods. This study aimed to establish the relationship between results generated by the CEM and Soxhlet methods utilized to measure lipid content in fresh pork loin.

Materials and Methods: Fresh pork loins ($n = 68$) were collected at a commercial pork processing facility and were aged 12 to 14 d. The fresh loins were collected from 3 processing dates (PD) (PD 1 $n = 13$, PD 2 $n = 29$, and PD 3 $n = 26$). Loins were from barrows ($n = 34$) and gilts ($n = 34$), and 3 sire lines (SL) (SL1 $n = 24$, SL2 $n = 23$, and SL3 $n = 21$). Loins were vacuum packaged and transported to Iowa State University. Aging time varied (12 to 14 d) to avoid freezing samples before sensory analysis. Loin chops (2.54-cm) were cut from the last rib region of each loin and trimmed of external fat. Marbling and color scores were assigned. Two chops per loin were cooked to an internal temperature of 68°C, and cook loss was calculated. Cooked chops were cut, and 1.5-cm cube samples were immediately delivered to a sensory panel ($n = 3$) for evaluation. A trained panel evaluated tenderness, juiciness, chewiness, pork flavor, and off-flavor using a 10-point scale. Eight samples were evaluated per session. An Instron fitted with a 5-point star probe attachment was used to measure instrumental tenderness on a cooked chop. The chops adjacent to those used for sensory analysis were homogenized using liquid nitrogen. Sixty-eight samples were analyzed in triplicate for lipid content using the CEM Oracle and Soxhlet methods. Data were analyzed using JMP (JMP Pro 16.1.0, SAS Institute Inc., Cary, NC). A Pearson correlation matrix was created to establish relationships between the pork quality traits analyzed between the two methods. A Spearman rank correlation analysis was conducted for CEM, Soxhlet, and marbling content. A regression model was created to evaluate the relationship between CEM and Soxhlet fat content.

Results: Spearman rank correlation between CEM and Soxhlet values was 0.89. The Spearman rank correlation between CEM and marbling was 0.73. The Spearman rank correlation of Soxhlet to marbling was 0.72. The regression analysis revealed a linear relationship between CEM lipid and Soxhlet lipid content (average Soxhlet lipid percentage = 0.30 + 0.99*average CEM lipid percentage; $R^2 = 0.81$). Pearson correlation coefficients between CEM lipid content and sensory tenderness, chewiness, juiciness, flavor, and off-flavor were estimated (0.30, −0.20, 0.29, 0.48, and −0.23, respectively). Similarly, Pearson correlation coefficients between Soxhlet lipid and sensory tenderness, chewiness, juiciness, flavor, and off-flavor were estimated (0.29, −0.18, 0.30, 0.47, and −0.22, respectively).

Conclusion: The results confirmed that CEM and Soxhlet values were highly correlated. The CEM and Soxhlet lipid content exhibited similar correlations to other pork quality traits. These results show that CEM Oracle and Soxhlet are equally valid to determine the lipid composition of fresh pork loins.

Funding Source: Funding, wholly or in part, was provided by the Iowa Pork Producers Association.

Keywords: CEM Oracle, lipid, pork loin, Soxhlet

## 104 DETERMINING WEIGHT AND LEAN YIELD OF PORK PRIMALS USING AN ON-LINE ADVANCED ULTRASONIC IMAGE ANALYZER (AUTOFOM III)

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Objectives: Prediction of primal weights and primal lean yield are not possible when using optical probe technology and are seldom measured on individual carcasses in the commercial pork industry. The purpose of this study was to determine the capabilities of on-line ultrasound technology (AutoFom III) to predict weights and lean yield of pork primals.

Materials and Methods: Pork carcasses ($N = 350$ carcasses; 173 barrows, 177 gilts) were selected from a population of 3,950 pigs from 17 different slaughter dates at a commercial pork processing facility based on hot carcass weight (107.6 ± 8.04 kg), back fat thickness (16.6 ± 3.8 mm), and sex (barrow or gilt). Hot carcass weights were divided into quartiles within sex for each load of pigs; any carcasses with carcass defects (i.e., missing components) were not considered for selection. Two or three carcasses were selected from each carcass weight quartile within each sex based on back fat thickness group (lean [≤ 15 mm], intermediate [15.5 to 19 mm], and excessively fat [≥ 19.5 mm]) for a total of 20 to 24 carcasses for a given slaughter date. Individual identity of the selected carcasses began during slaughter when AutoFom III measurements were collected on the entire carcass prior to evisceration and continued through carcass side dissection (24 to 28 hours postmortem). Carcass sides were fabricated according to North American Meat Processors Association International Meat Purchase Specifications with each carcass piece dissected into lean, fat, and bone. Model statistics for calibration and validation data sets for AutoFom III data were developed for this study by Frontmatec personnel. For the calibration ($N = 195$ carcasses), partial least squares regression was used to predict the measured traits from image parameters generated by AutoFom III software, and partial least squares models were optimized using interval partial least squares. For the validation ($N = 142$), linear regression analysis was used to examine the accuracy of the AutoFom III data for estimating weights and lean yield for bone-in primal weights.

Results: AutoFom III technology was moderately to highly accurate for predicting weights and lean yield of pork primals. The calibration study was successful with $R^2$ cross validation values ranging from $R^2 = 0.57$ to 0.84. This included $R^2$ cross validation values of 0.84 (whole shoulder weight), 0.67 (whole shoulder lean yield), 0.73 (picnic weight), 0.61 (picnic lean yield), 0.78 (butt weight), 0.65 (butt lean yield), 0.84 (loin weight), 0.82 (loin lean yield), 0.71 (belly weight), 0.63 (belly lean yield), 0.79 (ham weight), and 0.59 (ham lean yield). The validation study was also successful with $R^2$ prediction values ranging from $R^2$ 0.60 to 0.85. This included $R^2$ cross validation values of 0.72 (whole shoulder weight), 0.69 (whole shoulder lean yield), 0.61 (picnic weight), 0.60 (picnic lean yield), 0.60 (butt weight), 0.71 (butt lean yield), 0.80 (loin weight), 0.85 (loin lean yield), 0.77 (belly weight), 0.69 (belly lean yield), 0.64 (ham weight), and 0.61 (ham lean yield).

Conclusion: In summary, the AutoFom III data showed moderate to high levels of accuracy for predicting weight and lean yield values for pork primals. This could be of particular interest for the pork packing industry when looking for technologies that can better capture carcass merit on an individual primal basis.

Funding Source: Funding for this project was provided by Ontario Pork (Grant Number 18-003) and the Natural Sciences and Engineering Research Council of Canada.

Keywords: AutoFom, carcass prediction, carcass yield, pork grading, pork primals

## *105 FUNCTIONAL TRANSCRIPTOMICS OF BEEF: BIOMARKERS FOR MARBLING, LIPID OXIDATION, AND TENDERNESS*

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Objectives: Over the last decades, multiple technologies have been employed to predict beef quality. Recently, multi-omics techniques have been gaining popularity as tools to predict quality attributes. In this study, we presented genes as possible biomarkers for marbling and lipid stability and identified microRNA (miR) as biomarkers for meat tenderness.

Materials and Methods: Strip loin steaks from crossbred angus steers were tested for lipid stability and instrumental tenderness and grouped in 2 categories based on thiobarbituric acid (TBA) (MDA, stable: 0.07–0.1 mg/kg, and unstable: 0.15–0.43) and Warner-Bratzler shear force (WBSF; tender: 18.4–23.2 N, and less tender: 28.2–31.5 N) values ($n = 7$ per category, $n = 14$ total). For lipid oxidation steaks were aged for 7 d under vacuum conditions and displayed at 5°C ± 2°C under aerobic conditions for 8 d in a refrigerated case. Lipid oxidation was estimated at the end of the display. For tenderness, steaks were aged under vacuum conditions for 14 d and cooked, and WBSF was estimated by shearing 6 individual cores at day 14. For all samples, 2 g of the same muscle was collected on day 0 to estimate gene and miR expressions and further correlate the expressions to TBA and WBSF values. Correlations were also analyzed for marbling score (low = 315.48–370.17, and high = 400.43–505.97). Total RNA from 0-d samples was extracted and isolated via Triazol. Barcoded microRNA-sequencing libraries were prepared using the NEXTflex Small RNA Sequencing version 3 kit with randomized adapters. The libraries were quantified by fluorometry and sequenced with

single-end 100 bp reads. Data were analyzed using the SPORTS computational pipelines. Transcripts per million were used as the unit for expression. Differentially expressed miR were identified by the edgeR tool.

Results: Transcriptomic data suggested that 8 genes (*PC*, *CHPT1*, *GALNT17*, *THRSP*, *HEXIM1, GPC1, RNF207, SPATA2*, and *NT5M*) were positively correlated to marbling score and 10 genes (*LPP, ANTXR2, C1QB, IQGAP2, LUM, PTI, RAPGEF4, CISH, SPN*, and *FGL2*) were negatively correlated. One gene (*GLB1L2*) was positively correlated to lipid oxidation, and one gene (MLYCD) was negatively correlated. Overall, no miR was found to be correlated with marbling score and lipid oxidation. However, 33 miR were found to be significantly correlated with WBSF values (bta-mirs: 107, 103-1, 103-2, 6123, 99b, 423, 671, 193a, 361, 491, 339a, 362, 500, 93, 502b, 502a-1, 206, 128-1, 132, 505, 664b, 23a, 23b, 105a, 151, 25, 10a, 10b, 2478, 7d, 191, 125b-1, and 125b-2). R-values varied from 0.3 to 0.5.

Conclusion: Genes may be used as biomarkers for marbling score. However, gene expression does not seem to be the best indicator to identify biomarkers for tenderness. Previous research suggests that genes such as *ACTA1, HSPB1, MYH1, MYL1, TNNT3, CKM, ENO3, HSPB6*, and *HSPA1A* may be used as tenderness biomarkers. In this study, we did not observe reliable correlations between gene expression on day 0 postmortem and tenderness measured 14 d postmortem. MicroRNA modulate 60% of gene expression and may be found highly expressed postmortem up to 14 d. Although is expected that selected mRNA may be rapidly degraded postmortem, the expression levels of genes considered biomarkers for quality attributes begin to change from 24 h onward. This study suggests that miR may play a decisive role in gene silencing postmortem, and therefore they may be used as accurate biomarkers, especially for tenderness.

Keywords: beef, microRNA, tenderness

## 106 EVALUATING RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY AS A NOVEL, MINIMALLY INVASIVE, REAL-TIME METHOD FOR ASSESSING PORK BELLY QUALITY AND FAT COMPOSITION

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Objectives: Pork belly composition and bacon cooking performance are primary considerations for overall belly quality. To date, no technology exists to objectively measure these attributes simultaneously. Lab-based measurements of these characteristics are laborious, destructive, and time-consuming. Rapid evaporative ionization mass spectrometry (REIMS) is a novel, *in situ* analysis measuring the metabolomic profile in real time. The objective of this study was to evaluate REIMS as a real-time predictor of pork belly quality and fat composition based on objective measurements to improve product composition and quality.

Materials and Methods: In an attempt to create differences in fatty acid composition and iodine value (IV), pork bellies ($N = 526$) from pigs fed 3 diets with varying levels of predicted IV were analyzed for bacon yield, fat shattering, slice distortion, cook loss, fatty acid composition, and IV and analyzed using REIMS. REIMS analysis was conducted using a Synapt G2-Si Q-TOF equipped with a REIMS source and an iKnife sampling device in negative resolution mode. Using AMX software, intensities of spectra between 50.0 and 1,200.0 m/z were extracted into bin intervals of 0.5 m/z for each of 2 burns of a sample, applying background subtraction. Bin intervals were sorted in descending order by mean normalized intensity, with only bin intervals reaching a cumulative intensity of approximately 80% being retained for further analysis ($n = 335$). Canonical correlations were conducted to measure relationships between REIMS factors (created from factor analysis of REIMS bin intervals) and fatty acid composition measured on a gas chromatograph fixed with a flame-ionization-detector. These correlations were used to create a factor analysis model which then categorized individual samples into "Excellent," "Great," "Good," and "Poor" quality groups using scores from REIMS mass bins.

Results: The relationship between REIMS factors and fatty acids existed (canonical correlation not equal to zero) for both canonical correlation sets 1 and 2 ($P < 0.01$). Groups exhibited differences in #1 and #2 slices ($P < 0.01$); shatter score ($P < 0.01$); saturated, monounsaturated, and polyunsaturated fatty acids ($P < 0.01$, $P < 0.01$, $P < 0.01$, respectively); and resultant calculated IV ($P < 0.01$). Notably, the model trained from the metabolomic profile categorized a test set of data into original quality groups with an overall accuracy of 62%, with only 1 individual being misclassified by greater than 1 quality group difference (0.20%). Additionally, regression analysis of REIMS data estimated IV with an accuracy of 86%.

Conclusion: REIMS proved to be an effective technology in segregating individual pork bellies based on bacon yields, cook loss, and fatty acid composition. The use of metabolomic profiles collected in real time and *in situ* using REIMS characterized differences in degree of saturation of fat, which in turn translated to higher quality bellies with a greater proportion of premium #1 slices. These data suggest the ability of REIMS to improve the classification of the composition and quality of pork bellies based on an objective measurement captured in real time.

Funding Source: Pork Checkoff.

Keywords: bacon yield, belly composition, mass spectrometry, pork quality

## 107 EVALUATING VARIANCE (COEFFICIENT OF VARIATION) OF METABOLOMIC PROFILES OF BEEF GENERATED BY RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY

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Objectives: Rapid evaporative ionization mass spectrometry (REIMS) has shown classification potential in various applications of the meat and food industry through the utilization of machine learning algorithms. The accuracy of these algorithms is directly dependent upon the consistency and repeatability of the measured variables. Coefficient of variation (CV) is used to indicate repeatability within and between samples. Therefore, the objective of this study was to evaluate CV in metabolomic profiles generated by REIMS on a within- and between-sample basis across mass bins.

Materials and Methods: Metabolomic profiles of anterior portions of beef striploins (*Longissimus lumborum*; $n = 477$), collected from a previous study, were used to measure CV. A homogenate sample of a striploin section outside the study was also created and evenly split into conical vials ($n = 84$) to serve as an external standard. Each vial of homogenate was analyzed 3 separate times between each machine cleaning as the 1st, 30th, and 48th samples. During sample acquisition, each sample was analyzed in triplicate. Using AMX, intensities of spectra between 50 and 1,500 m/z were extracted into bin intervals of 0.5 m/z for each of 3 burns of a sample. The matrix was then uploaded to RStudio and normalized based on total intensity. Mass bins were then ranked using total intensity, and only those composing 80% of total intensity were retained for further analysis, resulting in 477 identified bins (of 2,879). Intrasample and intersample CV were then calculated. First, intrasample CV was calculated by calculating the mean CV of all bins for each striploin and homogenate sample. Second, intersample CV was calculated for all samples by dividing the standard deviation by the mean of each bin for both striploin samples and homogenate.

Results: The mean intrasample CV for striploin and homogenate samples were 12.0% and 12.6%, respectively. The intrasample CV range for striploin samples was 4.3% to 31.2%, and the homogenate yielded a mean intrasample CV range of 3.9% to 35.8%. Additionally, the mean intersample CV for all identified bins for striploin samples was 60.6% whereas the homogenate exhibited a mean intersample CV of 67.7%. As the number of bins selected increased from the 10 to 100 most abundant peaks, the mean intrasample CV was lower for striploin samples (8.0% vs. 10.7%) and homogenate (8.7% vs. 11.3%).

Conclusion: In conclusion, metabolomic profiles generated by REIMS yielded a wide range of intra- and intersample CV. However, a lower intrasample than intersample CV was measured and is likely due to the combined variance of whole muscle samples and machine sensitivity. The results of this study give an in-depth view of the variability that exists at the most basic level of REIMS data. Values comparable to those reported in this study are expected and acceptable for use in machine learning. Furthermore, this lays the initial groundwork for increasing repeatability while maintaining sample individuality in mass spectrometry data through data manipulation techniques.

Funding Source: United States Department of Agriculture/Agriculture and Food Research Initiative–Foundational and Applied Science.

Keywords: mass spectrometry, rapid evaporative ionization mass spectrometry, machine learning, beef, coefficient of variation

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## 108 A COMPARISON OF PORK CARCASS CHARACTERISTICS USING AN ADVANCED ULTRASONIC IMAGE ANALYZER (AUTOFOM III), AN OPTICAL GRADING PROBE (DESTRON PG-100), OR MANUAL CARCASS DISSECTION

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Objectives: The purpose of this study was to compare the accuracy of the following 3 methods for measuring back fat thickness (BFT) and muscle depth (MD) and for predicting lean yield (LY) in pork carcasses: 1) scanning the entire carcass with automated ultrasound technology (AutoFom III), 2) measuring BFT and MD at one location (i.e., the grading site between the 3rd and 4th last ribs, 7 cm off the mid-line) with a handheld optical grading probe (Destron PG-100), and 3) measuring BFT and MD at the grading site (i.e., actual ruler measurements) and calculating LY based on manual carcass side dissection (cut-out).

Materials and Methods: Pork carcasses ($N = 350$ carcasses; 173 barrows, 177 gilts) were selected from a population of 3,950 pigs from 17 different slaughter dates at a commercial pork processing facility based on hot carcass weight, BFT, and sex (barrow or gilt). Individual carcass identity of selected carcasses was maintained during slaughter where AutoFom III and Destron PG-100 measurements were collected and during transport/arrival to the University of Guelph Meat Laboratory (24 to 28 h postmortem). Upon arrival, pork carcass sides were fabricated according to North American Meat Processors Association International Meat Purchase Specifications. BFT and MD were measured with a ruler at the grading site

location, while LY was calculated using carcass side dissection data with the following equation: [(sum of the lean from the loin + picnic + butt + ham + belly + belly side ribs + neck bones)/cold left side weight] × 100. Data were analyzed with a 2 × 3 factorial arrangement in a randomized complete block design including sex, method for measuring predicted LY, and their interaction as fixed effects and producer (i.e., farm of origin) and slaughter date as random effects. Linear regression analysis was used to examine the accuracy of AutoFom III and Destron PG-100 data for estimating BFT, MD, and calculating LY when compared with actual BFT, actual MD, and calculated LY using the cut-out equation.

Results: There were method differences ($P < 0.01$) for determining MD and LY, whereas there were no method differences ($P > 0.26$) for measuring BFT. MD was greatest for the ruler measurements exceeding Destron PG-100 MD predictions by 1.8 mm and AutoFom III MD predictions by 2.1 mm. LY was lowest for the cut-out calculation. LY predictions were 5.6% and 2.2% greater, respectively, based on Destron PG-100 and AutoFom III equations when compared with LY calculated from a manual cut-out. Both AutoFom III and Destron PG-100 strongly predicted BFT and LY ($R^2 \geq 0.66$) but poorly predicted MD ($R^2 \leq 0.32$). Use of the AutoFom III improved accuracy ($R^2 = 0.77$, root mean square error = 1.83) for determining LY versus using the Destron PG-100 ($R^2 = 0.66$, root mean square error = 2.22).

Conclusion: This study demonstrates that the use of grading technologies (both ultrasound and optical probes) can be used to accurately predict BFT and LY for pork carcasses. However, it should be recognized that the ultrasound technology used in this study improved accuracy of prediction when compared with the optical probe technology used in this study. Additionally, the large differences between cut-out LY calculations and predicted LY supports the need for refinement of prediction equations.

Funding Source: Funding for this project was provided by Ontario Pork (Grant Number 18-003) and the Natural Sciences and Engineering Research Council of Canada.

Keywords: AutoFom, carcass prediction, lean yield, optical probe, pork grading

## 109 EFFECTS OF THE DIETARY CONCENTRATE LEVEL ON CARCASS CUTABILITY TRAITS AND CUTOUT PERCENTAGES OF SPANISH WETHERS AND DOELINGS

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Objectives: The number of meat goats produced in the United States has steadily increased since 1987 and saw a major increase from 415,196 to 2,622,000 in 2019 (USDA NASS). Thus, the objective of the study was to determine effects of dietary concentrate level on carcass traits of Spanish wethers and doelings.

Materials and Methods: At approximately 4 mo of age, 58 (29 wethers and 29 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 ingredients, 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 10 mo 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).

Results: Overall, males had heavier hot and cold carcass weights and were heavier muscled ($P < 0.05$) than the females regardless of diet. There were no significant changes in percentage of boneless closely trimmed retail cuts, 12th rib fat thickness, body wall thickness, fat cover, or confirmation from goats fed different concentrate diets. For adjusted fat thickness, goats fed the 20C and 40C were fatter ($P < 0.05$) than goats fed the 50C and 70C diets. Goats fed the 20C diet fed had the highest ($P < 0.05$) percentage of leg weight. In addition, goats fed the 40C diet had higher leg scores ($P < 0.05$) than goats fed the 20C and 60C diet. Goats from the 50C and 70C treatments had higher percentages of rack weight ($P < 0.05$) than goats fed the 20C, 40C, and 60C diets. However, goats fed the 40C or 60C diet had higher ($P < 0.05$) percentages of shoulder weight than the goats fed the 20C, 50C, and 70C diets.

Conclusion: In conclusion, there were no consistent trends for carcass traits or cutout percentages of goats from the varying concentrate diets.

Funding Source: American Institute for Goat Research, Langston University, Langston, OK.

Keywords: None

## 110 ALTERNATIVE FABRICATION AND MUSCLE PROFILING OF THE BEEF TOP SIRLOIN BUTT

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Objectives: Traditional fabrication of the beef top sirloin butt (NAMI #184) incorporates several muscles into a single steak, leading to decreased tenderness, inconsistent portion sizing, and less desirable eating experience for consumers. The objective of the study was to segregate individual muscles and muscle subunits of top sirloin butts collected from carcasses ranging in quality grade (QG), hot carcass weight (HCW), and ribeye area (REA) to discern yield of alternatively fabricated cuts.

Materials and Methods: Top sirloins ($N = 70$) were obtained from a commercial beef packer based on QG (USDA Select, $n = 36$, and Top Choice, $n = 34$), HCW (light $\leq 362$ kg, medium = 363–453 kg, heavy $\geq 454$ kg), and REA (small $\leq 27.8$ cm$^2$, medium = 27.9–40.6 cm$^2$, large $\geq 40.7$ cm$^2$). Whole top sirloin butts were weighed, and dimensional measurements (length, width, height) were recorded. Whole top sirloin butt subprimals were then alternatively fabricated, separating each individual muscle and muscle subunit. Weight and dimensional data were collected for the *Biceps femoris*, *Gluteus accessorius*, and *Gluteus medius* center-cut (whole, dorsal, and ventral). A $2 \times 3 \times 3$ factorial was evaluated for treatment effects (QG, HCW, REA) on weight and dimensional variability of individual top sirloin muscles. Data were analyzed using a mixed model analysis of variance using SAS version 9.4., with significance being determined at $P < 0.05$. Quality grade, HCW, REA, and their interactions were assumed as fixed effects. Treatment least-square means differences were assessed through pair-wise comparisons for significant effects. To account for inconsistent sample size, least-squares means was evaluated in data output.

Results: Weights of top sirloin butts were heavier for Select carcasses ($P < 0.001$) versus Top Choice and increased as HCW increased from light to heavy ($P < 0.001$), and REA increased from small to large ($P < 0.001$). For all individual muscles, weights were found to be heavier in Select carcasses compared with Top Choice (*Biceps femoris* [$P < 0.001$], *Gluteus accessorius* [$P < 0.001$], *Gluteus medius* [$P < 0.001$]). The muscle that presented the most weight and dimensional variability in the top sirloin butt was the *Gluteus medius*. Weight of the *Gluteus medius* whole showed a three-way interaction between all treatments ($P = 0.036$). It was found that the *Gluteus medius* dorsal subunit had a three-way interaction for width ($P = 0.004$), and the *Gluteus medius* ventral subunit had a three-way interaction for length ($P = 0.039$), confirming *Gluteus medius* muscles are longer, wider, and taller in Select carcasses and become larger as HCW becomes heavier and REA increases in size. Dimensional measurements of the *Gluteus accessorius* were not significant (length [$P = 0.565$], width [$P = 0.311$], height [$P = 0.819$]).

Conclusion: In general, individual muscles and muscle subunits of the top sirloin butt vary in weight and dimension given differences between QG, HCW, or REA. The muscle that presented the most weight and dimensional variability in the top sirloin butt was the *Gluteus medius.* Regardless of varying carcass traits, the *Gluteus accessorius* showed the most consistency in muscle weight and dimension, with dimensionality not being dependent upon QG or carcass sizing, allowing for more merchandising flexibility. The yield and dimensional analysis generated from this study will be a useful resource to wholesalers, retailers, and branded meat programs for portion sizing and added value.

Funding Source: We gratefully acknowledge financial support from the Idaho Beef Council.

Keywords: beef, dimensions, *Gluteus accessorius*, top sirloin, yield

## *111 UTILITY OF PORK QUALITY AND COMPOSITION TO PREDICT SENSORY QUALITY IN FRESH PORK LOIN CHOPS*

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Objectives: Pork quality is important in determining pork value, as consumer demand for high-quality pork in the global marketplace is high. Defining the relationship between fresh pork traits, composition, and sensory quality is important to predict consumer acceptance and retail value. This study aimed to determine the relationships between pork quality traits from fresh pork lions collected under typical harvest conditions and from commercially available genetic lines.

Materials and Methods: Fresh pork loins ($n = 114$) were collected on 3 different processing dates (PD) (PD1, $n = 40$; PD2, $n = 37$; PD3, $n = 37$) at a commercial facility that utilizes $CO_2$ stunning and deep chill. Loins were aged 12 to 14 d. Three sire lines ($n = 40$, 37, and 37), barrows ($n = 57$), and gilts ($n = 57$) were represented. Loin pH was measured 24 h postmortem. Loin chops (2.54 cm) were cut from the last rib region of each loin and trimmed of external fat. Marbling and color scores of the cut surface of the loin were assigned. Two chops per loin were cooked to an internal temperature of 68°C. Cooked chops were cut, and 1.5-cm cube samples were immediately delivered to a panel for evaluation. A trained panel ($n = 3$) evaluated tenderness, juiciness, chewiness, pork flavor, and off-flavor using a 10-point scale. Eight samples were evaluated per session. An Instron fitted with a 5-point star probe attachment was used to measure instrumental tenderness on a cooked chop from the center portion of the loin. Loin chops adjacent to those used for sensory analysis (approximately 100 g) were homogenized using liquid nitrogen. Lipid content was determined using

**Table 1.** Pearson correlation matrix among pork quality and composition traits

| | Aged pH | Marbling | Cook Loss % | Juiciness | Tenderness | Star Probe | Lipid % |
|---|---|---|---|---|---|---|---|
| 24 hour pH | 0.80 | 0.47 | −0.48 | 0.49 | 0.50 | −0.41 | 0.25 |
| Aged pH | 1.00 | 0.57 | −0.39 | 0.39 | 0.41 | −0.46 | 0.41 |
| Marbling | | 1.00 | −0.17 | 0.30 | 0.36 | −0.38 | 0.73 |
| Cook Loss % | | | 1.00 | −0.50 | −0.43 | 0.34 | −0.07 |
| Juiciness | | | | 1.00 | 0.65 | −0.20 | 0.23 |
| Tenderness | | | | | 1.00 | −0.43 | 0.25 |
| Star Probe | | | | | | 1.00 | −0.36 |
| Average CEM Fat | | | | | | | 1.00 |

the CEM method. The samples were evaluated in triplicate with the loin as the experimental unit. Data were analyzed using JMP software (JMP Pro 16.1.0, SAS Institute Inc., Cary, NC). The model included the fixed effects of sex, slaughter date, and sire line. A Pearson correlation matrix analysis examined the relationship between 24-h pH, aged pH, CEM lipid percent, visual marbling, sensory traits, cook loss, and star probe in fresh pork loins. Stepwise regression analysis was performed to establish prediction models for star probe and sensory tenderness.

Results: The results of the correlation analysis are shown in Table 1. Significant, positive correlations were noted between 24-h pH and sensory juiciness and tenderness. Lipid content was positively correlated with marbling, but a weaker correlation between lipid content and tenderness was detected. Stepwise regression for sensory tenderness showed that sensory tenderness was predicted by 24-h pH and cook loss: sensory tenderness = −15.6 + 4.3*(24-h pH) −0.09*(cook loss); R-2 = 0.30.

Conclusion: This study revealed that although lipid content is highly correlated with some traits, it was not highly correlated with all traits examined. In this experiment, pork tenderness was best predicted by a model that included pH, suggesting that the protein component significantly influences aged pork tenderness.

Funding Source: Funding, wholly or in part, was provided by the Iowa Pork Producers Association.

Keywords: pork, pork quality, sensory quality

# Meat and Poultry Quality

## *112 FREE AMINO ACID AND SHORT-CHAIN PEPTIDE CONTENT IN WET-AGED BEEF STRIP STEAKS*

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Objectives: Wet aging is employed to improve beef tenderness. Proteolysis during aging may alter free amino acid and peptide composition, which are water-soluble flavor compounds in beef. This study examined the effects of wet aging on the content of free amino acids and short-chain peptides in beef *longissimus lumborum* muscle.

Materials and Methods: Twenty boneless beef loins (NAMP #180) of USDA Select were purchased from a commercial packing plant. Each loin was divided dorsally into 4 equal portions, which were randomized to receive either 0, 7, 14, or 21 d of aging. Each portion was cut into two 2.5-cm thick steaks (for descriptive and consumer panels) and one 1.3-cm thick steak (for chemical analysis) from the anterior to the posterior end. Steaks were vacuum packaged individually and stored in the dark according to their aging treatments. After aging, steaks were stored at −20°C until further processing. Steaks 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, pulverized, and stored at −80°C until subsequent analyses. Water-soluble flavor compounds were extracted in cold water with the addition of rhamnose, norvaline, and 8-bromo-adenosine-5'-monophosphate as internal standards. 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 measured by a Thermo Scientific Pierce Quantitative Colorimetric Peptide Assay kit (#23275; Thermo Scientific, Waltham, MA) 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. Actual probability values were reported.

Results: The short-chain peptide concentration was 2.71, 3.66, 4.41, and 4.93 mg/g, increasing from day 0 to day 7, 14, 21, respectively ($P \leq 0.044$). Twenty-seven amino acids were quantified in the water-soluble fraction of the beef *longissimus lumborum* muscle. The predominant amino

acids were ALA, VAL, HIS, LYS, and GLY, ranging from 1.30 to 4.41 mmol/kg, whereas the least predominant ones were ABA, SAR, HLY, and ASP, ranging from 0.01 to 0.08 mmol/kg. ALA, VAL, LEU, and LYS increased from day 0 to 21 more than other amino acids, by 1.77 ($P \leq 0.018$), 1.11 ($P \leq 0.043$), 1.44 ($P < 0.001$), and 0.90 mmol/kg ($P \leq 0.015$), respectively. SER, PRO, ASN, GLN, and HIS decreased from day 0 to 7 ($P \leq 0.039$), then increased from day 7 to 21 ($P \leq 0.014$). GLU increased by 0.75 mmol/kg from day 7 to 21 ($P \leq 0.018$).

Conclusion: Wet aging alters the content of free amino acids and short-chain peptides in beef. They are important water-soluble flavor compounds that play critical roles in the flavor development of cooked beef.

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

Keywords: amino acids, beef steaks, total peptides, wet aging

## 113 EFFECTS OF ELECTRICAL STIMULATION ON TOTAL PEPTIDE AND FREE AMINO ACID CONTENT IN BEEF

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Objectives: Electrical stimulation (ES) is employed to improve exsanguination and beef tenderness. Literature has indicated that ES alters postmortem metabolism in muscles. This study examined the effects of ES on total peptide and free amino acid content as water-soluble flavor compounds in postmortem beef *gracilis* muscle.

Materials and Methods: The *gracilis* from 4 beef steers ($N = 4$) were sampled immediately after exsanguination (before stimulation [PRE]). The carcasses were then stimulated for 20 s at 20 V (ES-4, 120 V, Jarvis, Middletown, CT) and sampled again immediately after stimulation (POST) and 24 h after stimulation (H24). The sample was trimmed of external fat and connective tissues, 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. The extract was 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 determined by gas chromatography-mass spectrometry. Data were analyzed in a generalized linear mixed model with sampling time as a fixed effect and animal as random effect. The selection of the appropriate covariance structure for repeated measurement was based on 3 default Information Criteria calculated by SAS (SAS Institute Inc., Cary, NC) in the smaller-is-better format (Akaike's Information Criteria, Akaike's Information Criteria Corrected, and Bayesian Information Criteria; Kincaid, 2005). Actual probability values were reported.

Results: The total peptide content ranged from 1.69 to 1.99 mg/g and did not differ among time points ($P = 0.074$). Among all free amino acids, GLN, ALA, HIS, VAL, GLY, and β-ALA were the most predominant, with content ranging from 0.57 to 2.2 mmol/kg, whereas SAR, ASP, PHE, ASN, and MET were the least predominant, ranging from 0.04 to 0.07 mmol/kg. Among time points, PRE samples had more ($P \leq 0.032$) ALA, β-ALA, LEU, ILE, HYP, PHE, LYS, TYR, and TRP than both POST and H24 samples. PRE had 1.14 and 1.37 mmol/kg more ALA ($P = 0.002$) in addition to 0.21 and 0.22 mmol/kg more β-ALA ($P \leq 0.014$) than POST and H24, respectively. However, PRE samples had 0.02 mmol/kg more ASP as well as 0.27 and 0.36 mmol/kg more GLU than POST and H24 samples, respectively ($P \leq 0.034$).

Conclusion: Free amino acids are important flavor precursors. While ALA, ASP, and GLU are flavor amino acids, β-ALA is a precursor of GLU. These findings indicate that ES influences the postmortem development of water-soluble flavor compounds in beef.

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

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

# Meat and Poultry Quality and Composition - Measurement and Prediction

## 114 TRAINED SENSORY PANEL EVALUATION OF FOUR BEEF STRIP LOIN QUALITY GRADES

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Objectives: High marbled beef usually provides better eating satisfaction for consumers. Consumers usually grade high

marbled meat with better tenderness, juiciness, and flavor. Flavor accounts for nearly 55% of beef-eating satisfaction for US consumers, but a trained panel can split the beef flavor into different flavor notes. In this study, a trained sensory panel measured tenderness, juiciness, and incidence of desirable flavors and off-flavors in striploin steaks from 4 different quality grades.

Materials and Methods: Beef strip loins ($n = 80$) with 21 d of aging were selected from the Gordon Davis meat laboratory at Texas Tech University representing 4 quality grades (Prime, Top [upper 2/3] Choice, Low [lower 1/3] Choice, and Select]. The first 2.54-cm steak was obtained from each striploin, vacuum packed, and posteriorly cooked to a medium degree of doneness (71°C) in a Rational oven. Eight steaks per session (10 panels) were offered to 6 to 8 trained panelists (trained following the AMSA guidelines), and panelists were asked to rate tenderness, juiciness, beefy flavor intensity, browned, roasted, sour, metallic, fat-like, buttery, umami, liver-like, and oxidized flavors on a 0- to 100-point scale. Data were analyzed using the GLIMMIX procedures of SAS, and panelists were nested and included as a random effect. The novel part of this project will be executed in fall 2022. In the second part, steak samples will be evaluated using Rapid Evaporative Ionization Mass Spectrometry (REIMS), and the REIMS spectra will be compared with the trained panel evaluation results to determine the ability of REIMS to predict beef eating satisfaction.

Results: Prime steaks obtained higher tenderness and juiciness scores ($P \leq 0.05$) whereas Top choice, Low choice, and Select presented no statistical difference for these attributes. For flavor attributes, Prime steaks registered higher ($P \leq 0.05$) scores for browned, fat-like, and buttery flavor; Low Choice obtained higher scores for sour ($P \leq 0.05$) but were not statistically different from Select. On the other hand, Select steaks received higher scores for liver and oxidized. No statistical differences ($P > 0.05$) were found for beefy flavor, roasted, metallic, and umami.

Conclusion: Overall consumer satisfaction is a complex attribute. The beef flavor is a combination of different flavor notes. In this study, USDA Prime presented better scores for some desirable flavors like browned, fat-like, and buttery. On the other hand, Select and Low choice presented higher scores for some off-flavors like sour, liver, and oxidized.

Keywords: Beef, Trained Sensory Panel, USDA quality grade

## 115 CHARACTERIZING THE VOLATILE FLAVOR PROFILE OF BEEF LIVER TO ELUCIDATE THE DEVELOPMENT OF LIVER-LIKE FLAVOR IN WHOLE MUSCLE BEEF CUTS

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Objectives: The objective of this study was to characterize the volatile flavor profile of beef liver to identify potential volatile compounds contributing to liver-like flavor in whole muscle beef cuts.

Materials and Methods: Beef liver, tenderloin (*Psoas major*), flat iron (*Infraspinatus*), and chuck-eye (*Longissimus thoracis, spinalis dorsi, multifidus, complexus*) steaks were purchased from local grocery stores in Lubbock, Texas. Steaks were then assigned to either of 2 aging treatments (Fresh and Aged), where fresh steaks were cooked on the same day of purchase and aged steaks were stored in a cooler (0°C to 2°C) for 7 d in polyvinyl chloride overwrap packaging until cooking. Beef liver was not aged. Steaks and liver slices were cooked to 71°C on a clamshell grill set at 375°C. Immediately following cooking, steaks were trimmed of excess connective tissue, external fat, and seam fat and then snap frozen in liquid nitrogen. Samples were homogenized in a commercial food processor and then stored at −80°C until subsequent analysis. Volatile analysis was conducted using gas chromatography-mass spectrometry. Volatiles were extracted via solid phase microextraction, then injected onto the GC. A 5-level calibration curve was used to quantitate volatile compounds to ng/g. Significance was determined at $P < 0.05$.

Results: Liver produced the greatest concentration of carbon disulfide, 2-butanone, decanal, dodecanal, octane, toluene, p-xylene, methyl octanoate, methyl-pyrazine, furfural, 5-methylfurfural, 3-methyl-thiophene, benzaldehyde, and phenylacetaldehyde compared with all other treatments ($P < 0.05$). Fresh tenderloin produced similar concentrations of acetic acid, ethanol, nonane, butyraldehyde, heptanal, hexanal, nonanal, octanal, pentanal, and 2-pentyl furan ($P > 0.05$). Ethanol, 1-penten-3-ol, 2-methylbutanal, 2,5-dimethylpyrazine, 2-ethyl-3,5/6-dimethylpyrazine, and 2-pentyl furan concentrations were similar between aged tenderloin and liver ($P > 0.05$). Aged flat iron produced similar concentrations of butyraldehyde, hexanal, pentanal, and 2-pentyl furan compared with liver ($P < 0.05$).

Conclusion: The volatile profile of liver seemed to be composed mainly of aldehydes derived from lipid and Maillard reaction flavor development pathways. Cuts with similar volatile profiles compared with liver are suggested to produce detectable liver flavor. Sensory data are required to quantify perceivable liver flavor. These data, along with sensory data, have the potential to build predictive models to predict liver-like flavor development in whole muscle beef cuts. Additionally, volatile compound thresholds can be determined to increase understanding of the concentration at which volatile compounds are contributing to liver-like flavor.

Keywords: aging, beef, flavor, liver, volatiles

## 116 COMPARISON OF SLICE SHEAR FORCE VALUE AND USDA CERTIFIED TENDER IN "A" VERSUS "E" MATURITY BEEF CARCASSES

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Objectives: With the increase in demand and spike in prices of USDA Prime beef, the investigation of new and innovative production methods to upgrade beef from cull cows is warranted. If cull cows could be fed for prescribed amounts of time to achieve marbling scores representative of Prime or Choice from young beef, and ultimately produce a similar eating quality to those corresponding quality grades of young beef, this could provide a way to meet the consumer's desire for high quality beef. The objective of this study was to compare the differences in instrumental tenderness of beef *longissimus* muscle obtained from fed beef representing various marbling groups from young to old beef carcasses.

Materials and Methods: Sections measuring ~10 cm were removed from the anterior portion of the strip loin from carcasses representing Old maturity (O) beef ($n = 448$) and Young maturity (Y) beef ($n = 423$). Within maturity groups, carcasses were selected to represent marbling scores: Abundant to Slightly Abundant (PR), Moderate (MD), Modest (MT), Small (SM), and Slight (SL). For each sample, the muscle was portioned into four 2.5-cm-thick samples, one of which was utilized for slice shear force (SSF). On the day of collection (day 2 postmortem), the steaks assigned to SSF were cooked on a clamshell grill to an internal temperature of 70°C. SSF values were obtained immediately after cooking. Using ASTM guidelines, steaks were categorized as "Certified Tender" when SSF was 20.0 kg or less. "Certified Very Tender" included steaks with SSF values of 15.4 kg or less. Data were analyzed using PROC GLIMMIX of SAS with treatment combination as the fixed effect. Categorization in Tender and Very Tender were analyzed as binomial distributions.

Results: All steaks varying in quality grades among both A and E skeletal maturity have a similarly high Certified Tender percent passage ($P > 0.05$) rate, with the exception of SL-Y and SM-O ($P < 0.05$). PR-Y and MD-Y have the lowest SSF values ($P < 0.05$) and highest "Certified Very Tender" percent passage ($P < 0.05$) rate. PR-O, MD-O, MT-Y, and SM-Y sheared more similar ($P > 0.05$), and MT-O and SM-O similarly sheared the highest SSF value ($P > 0.05$). PR-O, MD-O, SM-Y, SL-Y, and SL-O have a similar "Certified Very Tender" percent passage ($P > 0.05$) rate, with MT-O having the lowest percent passage ($P < 0.05$) rate.

Conclusion: Age of the beef carcasses did not have a significant effect on Certified Tender passage rate for Prime steaks. The proven benefits in tenderness compared with lower-end Top Choice, Low Choice, and Select steaks will be desirable for consumers in food service and the retail case. Follow-up studies should include consumer panels and analysis of the chemical composition of old and young beef steaks through proximate analysis and Rapid Evaporative Ionization Mass Spectrometry.

Keywords: maturity, quality grade, steak, tenderness

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## 117 GENOME-WIDE ASSOCIATION STUDY FOR BACKFAT ACID COMPOSITION IN DUROC LINE SELECTED FOR HIGH INTRAMUSCULAR FAT CONTENT

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Objectives: The fatty acid profile of pork meat is an aspect of growing interest for the pork industry. A higher percentage of unsaturated fatty acids in pork can contribute to making it a healthier product with a greater presence as part of a balanced diet. In some specific markets, such as Iberian pork, the percentage of target oleic acid is extremely high (> 55%). Pig nutrition plays a main role in the fatty acid profile of pork. Specific diets with high contents of unsaturated fats on the last phase of the finishing period are used. Despite this, a great variability in fatty acid profile may be observed in final products, which is a great challenge for pork packers. The contribution of genetics to fatty acid profile in pork meat is poorly understood. In this study, a genome-wide association study (GWAS) was performed for backfat fatty acid composition in a population of Duroc pigs that are part of a commercial line (Iberduroc, Topigs Norsvin) that has been selected during years with special focus on meat quality traits such as intramuscular fat level and marbling.

Materials and Methods: Fat samples from 318 gilts (hot carcass weight; $89.7 \pm 0.57$) were collected on groups of 25 animals during 1 y and analyzed using Near InfraRed Spectroscopy (NIRS™ DS2500, FOSS IBERIA SA, Spain). Different fatty acids (C16:0; C16:1; C18:0; C18:2; C18:3; C20:1) were measured and used in a GWAS. A single SNP GWAS was performed using the GTCA software applying an animal linear model with a genomic relationship matrix. Significant associations were declared when the association between an SNP and a phenotype presented a $-\log_{10}(P) > 4$.

Results: GWAS analysis revealed a QTL on chromosome 14 for two different fatty acids: C16:1 and C18:0. Additionally, a QTL was also revealed on chromosome 7 for both fatty acids C16:1 and C18:0. Markers identified in this study explained 0.411 and 0.296 of genetic variance

and 0.123 and 0.167 of phenotypic variance for C16:1 (palmitoleic acid) and C18:0 (stearic acid), respectively.

Conclusion: Genetic influence on stearic acid percentage in pork fat is highly relevant because XXX is negatively correlated with oleic acid content and it affects the ratio of Omega 3 to Omega 6 fatty acids. This marker could be used as part of the breeding goal in the Duroc line or used for selecting boars based on customer demand in order to reduce variability of fatty acid profile of pork meat in its progeny.

Keywords: fatty acids, genotypic-phenotypic expression, meat quality, pork, pork quality

## 118 AN ASSESSMENT OF CARCASS HOT FAT TRIMMING TO IMPROVE CARCASS COMPOSITION, QUALITY, AND CHILLING RATE

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Objectives: Hot fat trimming describes the removal of visceral and subcutaneous fat from beef carcasses prior to chilling. The current market incentivizes heavier, fatter cattle, which makes chilling carcasses more difficult. Hot fat trimming could allow for optimization of the current scenario. Therefore, this study evaluated the impact of hot fat trimming on carcass composition, quality, and chilling rate.

Materials and Methods: Twenty cattle of varying size and composition were harvested under the supervision of US Department of Agriculture federal inspection at Texas Tech University Gordon W. Davis Meat Laboratory. Alternating left and right sides ($N = 40$) of the same carcass were hot fat trimmed (HFT; 0 cm remaining over the round and chuck; 6 mm remaining over the sirloin and loin, with the 7.62 cm area on either side of the 12th and 13th rib left untrimmed), and the alternate side remained untrimmed (Control). Temperature probes were inserted to monitor deep tissue temperature of the *semimembranosus, longissimus lumborum*, and deep chuck as well as surface temperature on the exterior of the chuck of all sides during chilling. Carcasses were intermittently sprayed with chilled water for the first 12 h postmortem. After 20 h of chilling, carcasses were ribbed, allowed to bloom for 20 min, and graded, and objective color measurements were obtained. Carcasses were fabricated, and whole muscle components (blade meat, neck meat, and inside round cap) were collected from each side and subjected to proximate analysis with near infrared spectrometry. Two strip loin steaks from each side were collected and assigned to 1 of 2 aging treatments (2 d and 14 d) and analyzed for slice shear force and sarcomere length (raw and cooked). The impact of HFT was measured on a within carcass basis using a one-way analysis of variance.

Results: Final mean temperatures (20 h) of the round, loin, and chuck were greater in the untrimmed sides ($P \leq 0.019$). The greatest difference occurred in the chuck, where the untrimmed side was approximately 2°C warmer than the trimmed side ($P = 0.001$). Conversely, final mean temperatures (20 h) were not affected at the surface of the carcass ($P = 0.057$). As was designed, preliminary yield grade and ribeye area were not different ($P \geq 0.181$) between the sides. Quality grade was unaffected ($P \geq 0.440$) by HFT. Visual ($P = 0.766$) and instrumental ($P \geq 0.098$) lean color measurements were not different. Compositional analysis with near infrared spectrometry indicated that HFT blade meat and inside round cap samples had a greater percentage of moisture ($P < 0.001$) and a lower percentage of fat ($P < 0.001$). No differences existed in slice shear force and sarcomere length ($P \geq 0.151$).

Conclusion: These results suggest that hot fat trimming is advantageous for achieving a lower temperature at the conclusion of the chilling period without affecting the quality of the carcass. Further research, with a larger sample size, is needed to confirm these findings.

Keywords: beef quality, chilling, composition, hot fat trimming, tenderness

## 119 COLOR MUSE SPECTRO 1 AS POTENTIAL SPECTROPHOTOMETER FOR EVALUATING COLOR IN MEAT

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Objectives: Instrumental measurements using spectrophotometers have been widely utilized in meat science to evaluate meat color and proportions of myoglobin forms. However, reputable spectrophotometers frequently cost upward of several thousand US dollars (USD), which may not be an option for some meat researchers. Therefore, exploring other spectrophotometers that are cheaper yet accurate and precise would be beneficial. The Color Muse Spectro 1 is of interest, because of its significantly cheaper price (~300 USD). Therefore, the objective of this study was to examine the efficacy of Spectro 1 in evaluating color and myoglobin forms in beef in comparison to HunterLab Miniscan XE Plus.

Materials and Methods: Twenty-four beef steaks were fabricated from 2 loins, measuring 2.54 cm in thickness, purchased from a local grocery store, and randomized into 2 groups. Group 1 ($n = 12$) was allocated for spectrophotometric and colorimetric analyses, whereas group 2 ($n = 12$) was designated for myoglobin reducing ability (MRA) and oxygen consumption rate (OCR) measurements. Each steak was placed on a Styrofoam tray overwrapped with oxygen-permeable polyvinyl chloride film and kept in a refrigerator at 4°C for a 14-d storage period. Each device was calibrated for each time point

according to their respective manuals and calibration plates, at illuminant A observable 10° degree. The aforementioned measurements were evaluated at 0, 3, 5, 7, and 14 d, with 10 replicates taken for each sample. A Tukey-Kramer multiple comparison test was performed to detect differences between means, with $P \leq 0.05$ considered statistically significant.

Results: Our results indicated limited differences in $L^*$ and $b^*$ between the two instruments during the first 7 d. However, at 14 d, Spectro 1 $L^*$ and $b^*$ values were lower than those of HunterLab Miniscan. Spectro 1 had on average 4 units greater $a^*$ value than HunterLab Miniscan across the 14-d period. Metmyoglobin was comparable between the two spectrophotometers. Yet Spectro 1 had a greater oxymyoglobin value, whereas HunterLab Miniscan possessed greater deoxymyoglobin. MRA did not differ throughout the 14 d, whereas OCR was found greater when measured by Spectro 1.

Conclusion: The Spectro 1 showed promise in detecting color during storage, specifically for $L^*$ and $b^*$. Additionally, Spectro 1 demonstrated an ability to measure MRA and metmyoglobin formation.

Keywords: Color Muse Spectro 1, HunterLab Miniscan XE Plus, meat color

# Meat and Poultry Quality

## *120 EFFECTS OF WET AGING ON DESCRIPTIVE FLAVOR OF BEEF STRIP STEAKS*

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Objectives: Wet aging is usually employed to improve beef tenderness. However, development of water-soluble flavor compounds during aging may also change beef flavor profile. This study examined the effects of wet aging on descriptive flavor attributes of USDA Select beef strip steaks.

Materials and Methods: Twenty boneless beef loins (NAMP #180) of USDA Select were purchased from a commercial packing plant. Each loin was divided dorsally into 4 equal portions, which were randomized to receive either 0, 7, 14, or 21 d of aging. Each portion was cut into two 2.5-cm thick steaks (for descriptive and consumer panels) and one 1.3-cm thick steak (for chemical analysis) from the anterior to the posterior end. Steaks were vacuum packaged individually and stored in the dark according to their aging treatments. After aging, steaks from 7 randomly selected loins were stored at −20°C until descriptive sensory analysis. Twelve panelists were trained for 12 h, with a focus on umami and bitterness tastes in the first 6 h, using inosine-5'-monophosphate (umami) and caffeine (bitterness) solutions. In the remaining 6 h, panelists were trained with beef steaks spiked with inosine-5'-monophosphate. Panelists cleansed their palate using unsalted crackers, apple slices, apple juice, and cold water between samples. The intensity of tenderness, juiciness, beef flavor, flavor intensity, fat-like, salty, sour, bitterness, umami, and off-flavor was evaluated on a continuous 0- to 15-cm scale, with 0 being least intense and 15 being most intense. On the day of the panels, steaks from 6 loins, thawed 24 h prior, were trimmed of external fat and connective tissues, wrapped in aluminum foil, and cooked in a convection oven until the internal temperature reached 71°C. Cooked steaks were rested for 3 min and cut to 1.3-cm × 1.3-cm × 2.5-cm cubes. Samples were placed in sample cups with 3-digit codes and served to at least trained 6 panelists within 10 min per panel. To prevent panelists' fatigue, panels were conducted on 7 different days within 2 wk. The responses from the panelists were recorded by Compusense software (N1H 1C5, Compusense, Ontario, Canada). The panelist responses were averaged and analyzed by the GLM procedure of SAS 9.4 (SAS Institute, Cary, NC) with aging time as the fixed effect and loin as the random effect. Means, if different, were separated by a protected $t$ test. Actual probability values were reported.

Results: No difference existed in tenderness, juiciness, beef flavor, fat-like, salty, sour, and bitterness among all aging treatments ($P \geq 0.107$). Flavor intensity of steaks on day 14 was greater than that of day 21 ($P = 0.009$). Steaks that were not aged (day 0) had a greater umami taste than those aged for 7 and 21 d ($P \leq 0.042$), whereas day-7 steaks had less off-flavor, described as metallic, oxidized, and cardboard, than steaks of other aging treatments ($P \leq 0.038$).

Conclusion: Wet aging influenced the umami taste and the flavor intensity of beef. Prolonged aging of 21 d may decrease the umami intensity of beef.

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

Keywords: flavor, beef, umami, wet aging

# Meat and Poultry Quality and Composition - Measurement and Prediction

## *121 EVALUATING THE EFFECT OF DIET AND SEX ON FRESH PORK BELLY AND BACON CHARACTERISTICS*

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Objectives: Increasing the amount of unsaturated fatty acids in the diet of market swine, by inclusion of dried distillers' grain with solubles (DDGS), has an impact on growth performance, belly firmness, and bacon yield. The purpose of this study was to evaluate the effects of diet and sex on fresh pork belly and bacon characteristics.

Materials and Methods: Barrows and gilts were fed 3 diets (A, B, C) in 4 phases, formulated by 3 different levels of DDGS to result in the predicted iodine values (A = 68.6, B = 71.9, and C = 81.1). Fed swine were harvested at a terminal market weight, and loin muscle depth and carcass percent lean data were collected for each carcass. From pork carcasses ($N = 526$), a 15 cm × 5 cm strip from the ventral midline, and the entire belly, was collected and subsequently shipped to a commercial bacon processing facility. Bellies were processed into bacon using the standard procedures of the commercial bacon facility. Fresh pork bellies were analyzed for iodine value and fatty acid composition. Bacon collected from corresponding bellies were analyzed for bacon yield, cook loss, slice distortion, and fat shattering. All data were analyzed using R statistical software, version 1.4.1106, and significance level was set at $\alpha = 0.05$ for all analyses. An analysis of variance and estimated marginal means were computed to fit a linear model with diet and sex as main effects. Pearson correlations of bacon and belly attributes and fatty acid compounds were calculated and tested for significance.

Results: The interaction of diet and sex impacted loin muscle depth and carcass percent lean ($P \leq 0.03$), whereas diet and sex independently showed differences in hot carcass weight and fat depth ($P < 0.01$). The 3 diets altered bacon yield, fatty acid composition, and calculated iodine values of pork bellies ($P \leq 0.04$), whereas sex solely impacted bacon cook loss percentage and total monounsaturated fatty acids and polyunsaturated fatty acids ($P \leq 0.04$).

Conclusion: The data from this study suggest that diet had a more substantial impact on belly and bacon characteristics than sex. Increasing levels of DDGS in the diet led to negative effects on belly and bacon yield as well as quality, regardless of sex.

Funding Source: Pork Checkoff.

Keywords: bacon quality, bacon yield, fatty acid composition, pork, pork nutrition

# Meat and Poultry Safety

## *122 EVALUATION OF SAMPLING METHODS FOR THE DETECTION OF SALMONELLA IN CECAL CONTENTS AND MESENTERIC LYMPH NODES DURING CATTLE HARVEST*

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Objectives: The objective was to identify one or more mesenteric lymph nodes (MLN) that can be practically sampled at harvest and to determine whether a sponge sample of the cecal interior is equivalent to a sample of cecal contents for *Salmonella* detection and serotyping. *Salmonella* can be present in cattle peripheral lymph nodes (LN), which may lead to contamination of beef trim. MLN and cecal contents are under investigation as possible sentinels because they are more feasibly sampled. Cattle intestines contain an ileocecal LN and variable number of smaller MLN with diverse locations and morphologies designated sporadic small MLN (ssMLN). The relative frequencies of *Salmonella* presence in the ileocecal LN and ssMLN had not been determined empirically. At harvest, cattle ceca occasionally do not contain the 10 g of content required for a sample. A sponge sample of the cecum interior ensures a cecal sample from every carcass. The ability of a cecal interior sponge sample to detect *Salmonella* compared with cecal contents had not been examined.

Materials and Methods: Each of 50 cattle intestines were sampled with 5 methods: Ileocecal MLN, Proximal ssMLNs, Distal ssMLNs, Cecal Content, and Cecal Sponge. For each intestine, 4 to 10 ssMLN were assigned to 2 separate samples, Proximal ssMLNs and Distal ssMLNs, based on their relative proximity to the cecum. An incision was made in the cecum, and 10 g of contents was removed to obtain the Cecal Content sample. A Cecal Sponge sample of the cecum interior was obtained using a 3M Sponge-Stick (Cat. No. SSL10BPW). *Salmonella* were cultured for detection and enumeration. Four *Salmonella* isolates per sample were serotyped. Sample methods were considered significantly different when $P < 0.05$ by a McNemar $\chi^2$ test.

Results: The ileocecal LN was reliably identified and quickly recovered from intestines. Recovery of ssMLN was more difficult and time consuming. Ileocecal MLN, Distal ssMLN, and Proximal ssMLN sample methods detected *Salmonella* for 20%, 8%, and 4% of the sampled intestines, respectively (Table 1). *Salmonella* detection by Ileocecal MLN and Distal ssMLN sample methods did not differ significantly ($P = 0.08$). *Salmonella* detection by Ileocecal MLN and Proximal ssMLN sample methods differed significantly ($P = 0.01$). In only one instance was the same serotype identified by all 3 MLN sample methods. Cecal Sponge and Cecal Content sample methods detected *Salmonella* in 34% and 30% of ceca, respectively (Table 1). *Salmonella* detection did not differ significantly ($P = 0.77$) between Cecal Sponge and Cecal Content sample methods (Table 1). The same *Salmonella* serotype was identified by Cecal Sponges and Cecal Contents from 9 intestines.

Conclusion: The ileocecal LN should be sampled to represent the MLN because *Salmonella* was detected more

**Table 1.** Detection and enumeration of *Salmonella* in cattle ceca and mesenteric lymph nodes

| Sample method | No. of samples | *% Sat.* detected | *% Sat.* enumerated |
|---|---|---|---|
| Cecal sponge | 50 | 34 | 2 |
| Cecal content | 50 | 30 | 6 |
| Ileocecal MLN | 50 | 20 | 8 |
| Distal ssMLNs | 50 | 8 | 4 |
| Proximal ssMLNs | 50 | 4 | 2 |

frequently, and it was logistically easier to obtain. A sponge should be used to sample cecal contents because it detected *Salmonella* at least as often as cecal contents and is logistically easier to collect. These methods will be used to determine whether *Salmonella* detection in MLN and cecal contents correlate to *Salmonella* contamination of peripheral LN.

Funding Source: This work was supported by the USDA Agricultural Research Service National Program 108—Food Safety (project 3040-4200-021) and the Beef Checkoff (project 2075). USDA is an equal opportunity provider and employer.

Keywords: cattle, cecal contents, lymph nodes, *Salmonella*

## *123 THE FECAL RESISTOME OF BEEF CATTLE FROM CONVENTIONAL GRAIN-FED AND GRASS-FED SYSTEMS IN THE WESTERN UNITED STATES*

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Objectives: Antibiotics have been utilized by the beef industry to improve animal health; however, the use of antibiotics may induce the development of antimicrobial resistance (AMR) in the bacteria of the production environment. These AMR bacteria and their AMR genes (ARG) may be transmitted to humans via fecal contamination of the meat. However, it is currently unknown whether various grass-fed and grain-fed systems impact AMR bacteria or ARG in cattle feces. Therefore, the objective of this study was to characterize and compare the fecal resistome of cattle raised in various grass-fed and grain-fed feeding systems in the Western United States.

Materials and Methods: Fecal samples were collected from individual cattle at 14 mo of age as a baseline and collected again from the same animals 2 d prior to harvest. Treatments included 1) steers finished in a feedyard and harvested at 18 mo (CON), 2) steers grass-fed for 20 mo (20GF), 3) steers grass-fed for 20 mo and finished on grain for 45 d (GR45), and 4) steers grass-fed for 25 mo (25GF). Grass-fed systems did not receive any antibiotics, whereas some cattle from CON and GR45 received therapeutic antibiotics, and all received Monensin in their feedlot rations. Total microbial DNA was extracted from samples and sequenced on Illumina NoveSeq 6000 platform. The qualified sequence reads were aligned to MEGARes, an AMR database. Shannon's and Chao's diversity were calculated and compared using one-way analysis of variance in R. The analysis of similarity and non-metric multidimensional scaling was performed between the treatments feeding system with alpha level defined as 0.05.

Results: Over 41 million qualified reads were aligned to 449 ARG that were classified into 35 classes of resistance and 79 mechanisms. The numbers of ARG identified for CON, 20GF, GR45, and 25GF were 422, 359, 400, and 140, respectively. Regarding the Chao 1 diversity, the 25GF group had the smallest value (106) compared with that

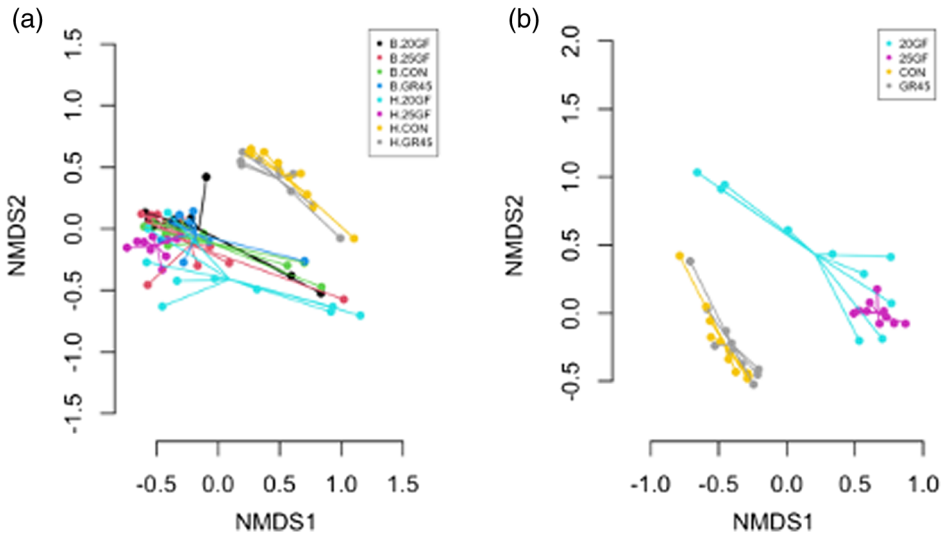


**Figure 1.** NMDS ordination plots of AMR genes composition. Non-metric multidimensional scaling (NMDS) ordination plots of AMR genes composition in fecal samples, (A) indicating significant difference (Stress = 0.08, R = 0.2111, P = 0.001) between conventional grain-fed (CON), 20 months grass-fed (20GF), 25 months grass-fed (25GF), and 25 months grass-fed and then grain-finished for 45 days (GR45) at baseline and harvest, (B) indicating significant difference (Stress = 0.06, R = 0.4038, *P* = 0.001) between CON, 20GF, 25GF, and GR45 at harvest.

of the other 3 treatments (CON 233, 20GF 164, and GR45 222; $P < 0.05$) at harvest time. Shannon's diversity suggested that the richness and evenness of ARG are greater in CON and GR45 compared with 20GF and 25GF ($P < 0.05$). The NMDS ordination plots of ARG composition indicated a significant separation (Stress = 0.08, $R = 0.2111$, $P = 0.001$) by treatments from baseline to harvest. Specifically, the ARG composition for GR45 and CON were different from those for the samples collected from grass-fed cattle at harvest time and all the samples at baseline. This separation became even more obvious when comparing the ARG composition among treatments only at harvest time (Stress = 0.06, $R = 0.4038$, $P = 0.001$).

Conclusion: This study characterized the fecal resistome of cattle from different production systems with different management practices regarding the use of antibiotics. The results indicated that conventional livestock feeding systems that utilized antibiotics therapeutically or prophylactically may enrich the diversity of the ARG in animals' feces, which may increase the potential transmission of AMR to human via contaminated meat, contributing to a higher level of risk of AMR in human.

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 resistance, antimicrobial resistant gene, cattle, resistome

## 124 BIO-MAPPING STUDY OF MICROBIAL INDICATORS AND PATHOGEN QUANTITATIVE LEVELS IN THREE COMMERCIAL BROILER PROCESSING FACILITIES IN SOUTH AMERICA

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Objectives: A bio-mapping study was conducted with the aim to create a microbiological baseline on indicators organisms such as aerobic plate counts (APC) and Enterobacteriaceae (EB), and on the quantitative enumeration and detection of *Salmonella* spp. and *Campylobacter* spp. in 3 commercial broiler processing facilities from the same country in South America.

Materials and Methods: Whole chicken carcass and wing (~2 kg) rinses were collected from 5 key stages of the poultry processing line: live receiving (LR), where a warm and intact recently identified death on arrival chicken was collected; rehanger (R); post-evisceration (PE); post-chilling (PC); and wings (W), using 400 ml of buffered peptone water. Rinses ($n = 150$, 50 per facility) were immediately chilled and transported for microbiological analysis. Microbial indicators were enumerated using the MicroSnap system for APC and EB, whereas the BAX-System-SalQuant and BAX-System-CampyQuant were used for *Salmonella* spp. and *Campylobacter* spp., respectively. Rinses that tested negative during enumeration were further enriched and evaluated using the BAX-System-*Salmonella* and the BAX-System-*Campylobacter* methodology for prevalence analysis, respectively. Counts were transformed into Log CFU/ml and ANOVA analysis followed by a pairwise-comparison *t* test adjusted Tukey ($P < 0.05$) was used for microbial indicators. *Salmonella* spp. and *Campylobacter* spp. counts were transformed into Log CFU/sample, and a Kruskal-Wallis analysis followed by a pairwise-comparison Wilcoxon's test and adjusted Benjamin–Hochberg method was used ($P < 0.05$).

Results: APC and EB counts were significantly different between stages at the processing line ($P < 0.01$). Average counts at LR were 7.33 and 6.08 Log CFU/mL for APC and EB, respectively. There was a significant reduction from LR to PC for both microbial indicators: 3.23 and 3.01 Log CFU/ml, for APC and EB, respectively. APC and EB counts increased significantly from PC to W (2.32 and 1.66 Log CFU/ml, respectively). The observed prevalence for *Salmonella* spp. was 26.6% for LR, 36.6% for R, 50% for PE, 10% for PC, and 33.3% for W. *Salmonella* spp. counts at PC were significantly different from the other stages at the processing line ($P = 0.03$). For *Campylobacter* spp., the observed prevalence was 93.3% for LR, 86.6% for R, 100% for PE, 86.6% for PC, and 86.6% for W. *Campylobacter* spp. counts were significantly higher than the other stages at PC ($P < 0.01$).

Conclusion: The development of bio-mapping baselines with microbial indicators showed consistent reduction up to the PC stage, followed by an increase at the W sampling location. The quantification of pathogens demonstrates that prevalence analysis as a sole measurement of food safety performance is not sufficient to evaluate the performance of processing operations and sanitary dressing procedures in commercial processing facilities.

Keywords: aerobic plate count, *Campylobacter* spp. enumeration, Enterobacteriaceae, *Salmonella* spp. enumeration

## 125 PREVALENCE OF NON-TYPHOIDAL SALMONELLA IN RETAIL CHICKEN AND TURKEY MEAT IN SOUTHERN CALIFORNIA FROM 2018 TO 2021

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Objectives: Poultry is a known source of foodborne *Salmonella* infections in humans. The objective of this study, using National Antimicrobial Resistance Monitoring System (NARMS) samples, was to determine the prevalence of *Salmonella* in retail poultry products from southern California.

Materials and Methods: Between January 2018 and December 2021, a total of 995 retail samples including 618 chicken and 377 ground turkey were purchased from randomly selected grocery stores in southern California. Sample information (e.g., organic and/or antibiotic-free label claims, packed in store or pre-packaged, and packaging type) were also recorded. Samples were transported to the laboratory on ice, refrigerated, and processed within 96 h of collection. Sample processing and *Salmonella* isolation were conducted based on the NARMS Retail Meat Surveillance Protocol. Statistical analysis was performed using R-studio. The prevalence of *Salmonella* was calculated by dividing the number of positive samples by the total number of samples in each category and multiplied by 100. Fisher's exact test and its post hoc analysis with adjusted *P* values were performed to determine the significant differences in prevalence among different types of samples using R package rcompanion. The alpha level was defined as 0.05.

Results: The overall prevalence of *Salmonella* was 17.29% across all samples and years, including a significant ($P < 0.05$) difference between chicken (22.17%) and turkey (9.28%). Prevalence in all samples in 2018, 2019, 2020, and 2021 was 6.94%, 29.16%, 18.8%, and 13.51%, respectively, and it significantly ($P < 0.05$) differed among sampling years. The lowest prevalence in chicken was observed in 2018 (7.92%), whereas the highest was observed in 2019 (39.58%). The prevalence in turkey was relatively consistent throughout the 4-y period. The prevalence in chicken and turkey was relatively static across seasons ($P > 0.05$), except in 2018 between winter (3.33%) and summer (40%). *Salmonella* prevalence was significantly different ($P < 0.05$) among products (breast, legs, wings, whole chicken, and mixed parts) sampled, with the highest prevalence observed in whole chicken (63.22%). No significant differences were found between organic and non-organic production claims. The prevalence of *Salmonella* differed significantly ($P < 0.05$) in packaging types, with the highest in vacuum packaging (54.24%) followed by paper (20.93%), traditional overwrapping film (14.71%), and modified atmosphere packaging (12.15%).

Conclusion: The relatively higher prevalence of *Salmonella* in chicken in our study may be attributable to changes in the 2019 NARMS laboratory protocol and the higher number of whole chickens collected and overnight incubation of whole chicken carcass in our lab in that year. Similar findings have been previously reported by the US Department of Agriculture (Simmons et al., 2003). The Food Safety and Inspection Service (https://www.fsis.usda.gov/sites/default/files/media_file/2022-02/sampling_project_results_data_20220127.pdf) is a good resource for a representative and nationwide picture of *Salmonella* in raw meat and poultry. Our study findings with chicken and turkey highlight the need to follow appropriate handling and cooking practices to minimize risks of foodborne salmonellosis. This study also emphasizes the importance of continuous pathogen surveillance in animal-derived foods by the NARMS and Food Safety and Inspection Service.

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Keywords: chicken, meat, prevalence, *Salmonella*, turkey

## *126 BIO-MAPPING OF SALMONELLA SPP. PREVALENCE AND QUANTIFICATION LEVELS IN MARKET HOG LYMPH NODES AND TONSILS FROM COMMERCIAL PROCESSING FACILITIES*

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Objectives: The purpose of this study was to determine prevalence and concentration levels of *Salmonella* spp. from 6 lymph different lymph nodes (LN) and tonsils of market hogs using a novel and rapid quantification methodology.

Materials and Methods: Pork LN (mesenteric, subiliac, superficial inguinal, pre-scapular, tracheobronchial, and axillary) and tonsils were collected from 99 different animals during harvest operations in commercial processing facilities during winter, chilled, and shipped overnight to the International Center for Food Industry Excellence Food Microbiology Laboratory at Texas Tech University for microbial analysis ($N = 693$). LN were trimmed, sterilized, pulverized, and homogenized with 80 or 30 ml of BAX-MP (LN homogenate [LNH]) according to their weight. From each LNH, samples were enumerated using the BAX-System-SalQuant methodology for pork LN. *Salmonella* prevalence was evaluated on each LNH that tested negative during enumeration using the BAX-System-*Salmonella*. Counts were transformed into Log CFU/sample, and $\chi^2$ and Kruskal-Wallis analysis were conducted to determine differences in prevalence and concentration levels, respectively, between samples with a 0.05 probability threshold.

Results: There was a significant difference ($P < 0.001$) in prevalence between samples. The observed prevalence for *Salmonella* spp. was 48.48% (48/99), 33.33% (33/99), 11.11% (11/99), 2.02% (2/99), 1.01% (1/99), 1.01% (1/99), and 1.01% (1/99) for tonsils, mesenteric, tracheobronchial, superficial inguinal, axillary, pre-scapular, and subiliac LN, respectively. Enumeration analysis showed that 34% of those harboring *Salmonella* spp. (19/56) did so at concentrations ranging from 1 to 4 Log CFU/sample, whereas 66% carried a higher load of *Salmonella* spp. with levels up to 7.26 Log CFU/sample. There was a significant difference ($P < 0.001$) in *Salmonella* spp. levels between samples resulting in tonsils, mesenteric, and tracheobronchial LN being different between each other and against superficial inguinal, subiliac, axillary, and pre-scapular LN.

Conclusion: The differences in prevalence and enumeration between LN show evidence that *Salmonella* can be harbored at higher rates and levels in specific LN in the animal. These findings may be used as industry guidance in order to understand how *Salmonella* spp. can be present and at which concentration in different LN of the animal so that risk-based decisions can be taken for product safety optimization.

Keywords: mesenteric, pork lymph nodes, *Salmonella* enumeration, SalQuant, subiliac

## *127 EVALUATION OF THE IMPACT OF AVIAN, BOVINE, AND PORCINE FECAL RESISTOMES ON SUBSEQUENT RESISTOMES THROUGHOUT PRODUCTION*

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Objectives: The discovery of antibiotics for human and animal use is considered one of the greatest medical advancements. However, the widespread use of antibiotics has caused concerns about a potential increase of antimicrobial resistance genes (ARG) within microbial communities. Microbes can acquire ARG through horizontal gene transfer or mutations, which both result from environmental pressures. Many consumers consider antibiotic usage in animal agriculture to be a vector for an increased abundance of antimicrobial-resistant microorganisms in humans and the environment through meat consumption and manure application as a soil amendment. Therefore, the objective of this study was to evaluate the relationships between the fecal resistomes of different food animal species (avian, bovine, and porcine), the resistomes of meat from those animals, and the resistomes of soil in which feces were used as an amendment.

Materials and Methods: Composite fecal samples ($n = 20$/species) were collected from each commercial production facility, and meat rinsate samples ($n = 20$/species) were collected for each species at the time of harvest. After harvest, feces and litter were composted and applied as an amendment on agricultural land. After one growth season, soil samples ($n = 20$/species) were collected separately for each species. Additionally, human waste solids were collected from wastewater treatment plants near each animal production operation ($n = 14$/species), and soil samples amended with human waste solids were collected ($n = 7$/species) from fields in close proximity to the broiler and bovine facilities. DNA was extracted, and the resistome library was prepped using the SureSelectXT reagent kit and used to prepare samples for target-enriched resistome sequencing. A custom bait design targeting ARG, MEGaRICH, was used to enrich sequencing libraries, which were sequenced on an Illumina NovaSeq intstrument using paired-end chemistry. De-multiplexed reads were analyzed using AMR++ v2 pipeline, and sequences were aligned to the MEGARes version 2 database to identify ARG. Richness, evenness, and Shannon's diversity were calculated. Beta-diversity was analyzed using Bray-Curtis dissimilarity distances, and hierarchal clustering was performed using Ward's agglomeration.

Results: Regardless of species, fecal samples had a greater ($P < 0.05$) richness and evenness of ARG compared with both meat and soil samples. For beta diversity, all the sampling types clustered ($P < 0.05$) individually (feces, meat, and soil) within species. Furthermore, within species each environment was dominated by different classes of ARG, indicating that they have different resistomes. When resistance groups medically important for human health were considered, human waste samples had a greater ($P < 0.05$) percentage (13%) of medically important resistance groups compared with all animal fecal samples (<5%).

Conclusion: The resistome of feces was richer and more diverse and clustered independently from both meat and soil indicating that feces had a more unique resistome across the different species. This suggests that the fecal resistome may not strongly influence meat and amended soil resistomes. Additionally, the lower relative abundance of medically important resistance groups found in animal feces suggests that food animal production may not be a significant source for antimicrobial resistance transmission to humans via animal agriculture.

Funding Source: United States Department of Agriculture–National Institute of Food and Agriculture.

Keywords: beef, broiler, human, pork, resistome

## 128 EVALUATING SUBOPTIMAL TIME-TEMPERATURE PARAMETERS IN SOUS VIDE COOKING FOR THERMAL INACTIVATION OF LISTERIA MONOCYTOGENES, SALMONELLA ENTERICA, AND MESOPHILIC AEROBIC BACTERIA AND EXTENT OF OUTGROWTH DURING REFRIGERATION

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Objectives: Sous vide, a French term meaning "under a vacuum," is a cooking method used widely in food service and home. In this method, meat is vacuum packed in heat-resistant plastic bags and cooked in circulating water at lower temperature and for a longer time. Meat may then be crash chilled, stored, and rewarmed to serving temperature later. Sous vide is popular because of its ability to provide uniformity of cooking, ease of handling, and improved timing. However, recommended parameters often only include time and temperature of cookery and may not account for a range in come-up time influenced by meat versus water volume or account for the wattage of the cooking device, which can cause incomplete pathogen lethality. Therefore, the objectives of this study were to evaluate the effect of suboptimal time-temperature parameters on thermal inactivation of *Listeria monocytogenes*, *Salmonella enterica*, and Mesophilic Aerobic Bacteria (MAB) and determine extent of outgrowth during subsequent refrigeration.

Materials and Methods: Eye of round was cut into 100-g, 1" thick steaks and inoculated with 5 strains of *Salmonella* and 3 strains of *Listeria* at a rate of 8 log CFU/g. After pathogen attachment (30 min) and vacuum packaging, meat (1 ± 0.2 kg) was cooked at 60°C, 57.5°C, and 52.5°C in 9 L water with a 1,000 W sous vide cooker. The samples were removed every 8, 15, and 45 min for 60°C, 57.5°C, and 52.5°C, respectively, and crash chilled on ice. Remaining *Salmonella*, *Listeria*, and MAB were enumerated using xylose lysine tergitol agar, modified oxford agar, and tryptic soy agar, respectively. Based on results from trial 1, we cooked additional steaks using cooking parameters that left a target of 3 log CFU/g of respective pathogens. After crash chilling, samples were stored at 3°C and 8°C for 2, 4, 6, and 8 d and enumerated. Data for both experiments were analyzed using the GLIMMIX procedure of SAS (version 9.4).

Results: Three cooking temperatures take different lengths of time ($P < 0.001$) for 5-log reduction in *Salmonella* (24 min [60°C], 30 min [57.5°C], 90 min [52.5°C]), *Listeria* (40 min [60°C], 60 min [57.5°C], 315 min [52.5°C]), and MAB (40 min [60°C], 75 min [57.5°C], 315 min [52.5°C]) in 1" thick steaks. Regardless of cooking temperature, no increase of *Salmonella* was seen out to 8 d of storage ($P = 0.486$); in fact, *Salmonella* reduced from day 0 (3.8 ± 0.47 log CFU/g) to day 4 (2.5 ± 0.47 log CFU/g) and stayed constant thereafter. *Salmonella* ($P = 0.66$) and *Listeria* ($P = 0.18$) growth at these cooking temperatures was not affected by storage temperature. However, *Listeria* in samples cooked at 52.5°C increased 0.2 log CFU ($P = 0.02$) during 8-d storage compared with higher temperatures. MAB growth was neither affected by refrigeration temperature ($P = 0.25$) nor storage duration ($P = 0.54$).

Conclusion: With the current cooking parameters, a 5-log reduction of both *Salmonella* and *Listeria* was observed within common recommended times, albeit with a narrow margin for safety. When inactivation is inadequate, *Listeria* from samples cooked at 52.5°C grew faster compared with samples cooked at higher temperatures, suggesting that the lower temperature has an increased risk of outgrowth. *Salmonella* is less resilient to sous vide cooking compared with *Listeria* and showed no potential for outgrowth during subsequent refrigeration at <8°C.

Funding Source: Florida Beef Council.

Keywords: food safety, food service, heat stress, thermoinactivation, thermotolerance

## 129 DEVELOPMENT AND VERIFICATION OF RAPID SALMONELLA ENUMERATION ESTIMATES UTILIZING PCR-BASED QUANTIFICATION METHODOLOGIES

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Objectives: It is well-established that the risk of human illness is based on dosage at the time of consumption, with some estimates around $10^4$ cells needed to cause illness for most types of *Salmonella* spp. There is a need to move beyond simple detection of *Salmonella* and toward enumeration to make informed decisions. Traditional enumeration protocols such as plate counts are not feasible for industry use as a monitoring tool as they take 24 to 48 h for estimated

results plus additional time for confirmation. The accurate evaluation of total numbers of pathogens is crucial for the industry as well as for microbial challenge studies. There is a need for rapid quantification methodologies for enumeration combined with a simplified workflow that increases lab productivity and yields accurate results for multiple *Salmonella* strains for decision-making by industry and for laboratory research studies. The objective of this study was to develop a rapid and reliable RT-PCR enumeration method that can accurately estimate the total quantitative numbers of 7 serotypes of *Salmonella* in pure culture preparations.

Materials and Methods: Pure cultures of *Salmonella* Typhimurium, *S.* Enteritidis, *S.* Dublin, *S.* Newport, *S.* Heidelberg, *S.* Reading, and *S.* Braenderup were grown in Tryptic Soy Broth to approximately $1 \times 10^9$ CFU/ml individually with 3 replicates per serotype. Serial dilutions were conducted on each culture ranging from $10^0$ to $10^{-4}$ Log CFU/ml. All dilutions were evaluated in triplicate by direct plating in Tryptic Soy Agar plates and in quintuplet using the BAX System utilizing the Real-Time PCR Assay for *Salmonella* spp. Cycle threshold values were grouped by genus, and a linear-fit equation utilized for quantification was created using JMP version 15 and compared using $R^2$, Log RMSE (Root Mean Squared Error) and plate counts.

Results: The rapid PCR-based system accurately enumerated $10^9$ to $10^5$ Log CFU/ml for various *Salmonella* strains in pure cultures when compared with traditional AOAC validated methods. The side-by-side comparisons were evaluated and calculated into a linear-fit equation to determine statistical relevance. All linear-fit equation estimations met statistical parameters with a $R^2$ value of 0.901 and a Log RMSE of 0.43 when statistically compared with plate counts based on a 95% confidence interval. This indicated that the rapid PCR-based enumeration method was equivalent to the traditional plate count method. These results were seen across all *Salmonella* strains utilized within this study.

Conclusion: The implementation of a rapid, PCR-based enumerative method for pure culture testing capabilities provides the food industry and microbial validation researchers with a tool to reduce the time to result needed to confirm inoculation concentrations providing less variation when conducting challenge studies and validation studies. *Salmonella* quantification is also critical for the industry in making risk-based and data-driven food safety decisions for management and product development.

Funding Source: The funding for this research project was provided through a collaboration between Texas Tech University and a private industry partner.

Keywords: enumeration, industry, polymerase chain reaction, *S.* Dublin, *Salmonella*

## *130 PROCESS VALIDATION FOR THE REDUCTION OF SURROGATE ESCHERICHIA COLI DURING THE CURING AND DRYING OF BILTONG*

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Objectives: Current guidelines recommend achieving a 5-log reduction of *Escherichia coli* via thermal processing. The objective of this research was to validate a process for the reduction of surrogate *E. coli* during the manufacture of Biltong, a South African–style dried meat product while adhering to traditional, non-thermal processing techniques.

Materials and Methods: Beef eye of rounds were sliced 2.54 cm thick and inoculated with a 5-strain cocktail of ATCC BAA-1427-31 surrogate *E. coli*. Inoculated samples were subjected to treatments with varying levels of salt, vinegar, lactic acid, and nitrites based on trial. Trial 1 samples were subjected to 3.75% salt, 21.3% apple cider vinegar (5% acetic acid), 156 ppm $NaNO_2$, and common ingredients found in traditional South African Biltong; Trial 2 samples were assigned to 1 of 9 treatments in a $3 \times 3$ factorial with 1.7%, 2.2%, or 2.7% NaCl and apple cider vinegar brine at 2%, 4%, or 6%. All treatments were formulated to include 156 ppm $NaNO_2$. Trial 3 samples were assigned to 1 of 4 treatments (no $NaNO_2$): Treatment 1 (2% NaCl, 2.5% vinegar), Treatment 2 (2% NaCl, 2.5% vinegar, 30 s 3% lactic acid dip), Treatment 3 (3.5% NaCl, 5% vinegar), and Treatment 4 (3.5% NaCl, 5% vinegar, 30 s 3% lactic acid dip). Samples were placed in a drying cabinet set at 15.5°C and 65% relative humidity. Samples were analyzed for pH, water activity ($A_w$), and proximate and microbial analysis after Inoculation, Post-Lactic Acid, Post-Salt, Post-Rinse, Post Brine, and at $A_w$ levels of 0.85, 0.80, and 0.75 depending on trial. For microbial analysis, samples were aseptically removed and placed in a sterile stomacher bag with 0.1% buffered peptone with rifampicin, stomached, serially diluted, and plated on APC Petrifilm or TSA with Rifampicin. Trials were conducted with multiple replications, and statistical analysis was performed using PROC GLM (SAS version 9.4).

Results: Trial 1 had a Time effect ($P < 0.01$) in which Log CFU *E. coli* and $A_w$ decreased with time achieving a 5-log reduction after 14 d and $A_w$ 0.85. Trial 2 had no Treatment × Time interaction or Treatment main effect for surrogate *E. coli* counts ($P > 0.34$). There was a Time main effect ($P < 0.01$) with Log CFU *E. coli* decreasing at each sampling time point. Treatment did not affect $A_w$ or pH; however, there was a sampling Time effect for both ($P < 0.01$). Trial 3 did not have a Treatment × Time interaction ($P > 0.83$) for Log CFU *E. coli*; however, there were Time and Treatment main effects ($P < 0.01$). There was

not a Treatment main effect ($P > 0.25$) for $A_w$, but there was a Time main ($P < 0.01$) with $A_w$ decreasing with time. Trials 1 and 3 achieved a 5-log reduction of surrogate *E. coli* by $A_w$ 0.85. Trial 2 was unable to achieve a 5-log reduction; however, after drying to $A_w$ 0.80, all samples achieved a 2-log reduction. Further drying to $A_w$ 0.75 met a 5-log reduction for 3 of the 9 treatments.

Conclusion: This study showed that it was possible to achieve a 5-log reduction for surrogate *E. coli* in whole muscle dried products without thermal processing. This work should be followed by studies utilizing pathogenic *E. coli* O157:H7 and non-O157 STEC for further validation.

Keywords: Biltong, *Escherichia coli*, STEC

## 131 EFFECT OF FAT CONTENT ON SALMONELLA LETHALITY ON THE SURFACE OF IMPINGEMENT-COOKED PORK PATTIES

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Objectives: Revisions to the US Department of Agriculture Food Safety and Inspection Service cooking guideline (Appendix A) state that relative humidity is necessary to achieve *Salmonella* inactivation on product surfaces in high-temperature, short-time cooking processes. Current research suggests that low-fat products cooked in such processes may promote surface dehydration, resulting in less *Salmonella* lethality at the surface. However, this phenomenon is not well understood. The objective of this study was to quantify the effect of fat content on *Salmonella* lethality on the surface of impingement-cooked pork patties in processing conditions with and without added humidity.

Materials and Methods: Pork patties (5%, 15%, 30%, 50% fat) were surface inoculated with an 8-strain *Salmonella* cocktail and cooked at 218.3°C target dry-bulb under processing conditions either with added humidity (71.1°C target wet-bulb) or without added humidity (ambient wet-bulb) in a pilot-scale, two-zone impingement oven. Samples were cooked for 1 min 55 s per zone to target an internal temperature of 70°C. Oven and product temperatures were recorded for each treatment. Duplicate samples from 3 replications were collected at pre-cook and after each zone, immediately placed in chilled BPW, and plated on selective/differential media. Significance for fat content and processing condition effects were determined by ANOVA.

Results: At ambient wet-bulb condition, fat content had a significant effect on total *Salmonella* log reduction ($P = 0.03$). This suggests that low-fat products were prone to surface dehydration leading to desiccated, heat-tolerant *Salmonella*. In comparison, total *Salmonella* log reduction at all 4 fat contents were not significantly different at the 71.1°C target wet-bulb condition ($P > 0.05$). Analyzing all treatments from both processing conditions together showed no fat content or process condition effect ($P > 0.05$). The average log reduction for all fat contents at 71.1°C target wet-bulb condition was higher than ambient condition (6.35 vs. 5.60 log, respectively).

**Table 1.** Cook process parameters per zone[a] and total log reductions of *Salmonella*[b] on the surface of pork patties.

| Process targets and settings per zone | | | | |
|---|---|---|---|---|
| Product | Dry bulb (°C) | Wet bulb (°C) | Dwell time (mm:ss) | Total log *Salmonella* reduction[b] |
| 5% fat Pork | 218.3 | ambient | 1:55 | 4.63 ± 0.56 |
| | 218.3 | 71.1 | 1:55 | 6.16 ± 1.15 |
| 15% fat Pork | 218.3 | ambient | 1:55 | 5.31 ± 0.80 |
| | 218.3 | 71.1 | 1:55 | 6.50 ± 0.83 |
| 30% fat Pork | 218.3 | ambient | 1:55 | 5.50 ± 1.11 |
| | 218.3 | 71.1 | 1:55 | 6.26 ± 1.52 |
| 50% fat Pork | 218.3 | ambient | 1:55 | 6.96 ± 1.64 |
| | 218.3 | 71.1 | 1:55 | 6.49 ± 1.42 |

[a]Two-zone impingement oven (Model 1832-01596, XLT Ovens, Wichita, KS) equipped with steam injection for controlling wet-bulb temperature in each zone.

[b]Total log *Salmonella* reductions shown are the mean of three replicates and expressed as mean ± standard deviation.

Conclusion: The results show low-fat products have lower *Salmonella* lethality at the surface when cooked in ambient desiccation-supporting conditions when compared with higher-fat products. However, they show minimal fat effect when surfaces are exposed to conditions with added humidity (71.1°C target wet-bulb) due to the product surfaces remaining hydrated while exposed to a lethal time and temperature combination. The findings provide useful information to the US Department of Agriculture Food Safety and Inspection Service and the meat industry to ensure sufficient surface lethality for products cooked in high-temperature, short-time processes.

Keywords: Appendix A, hydrated surface lethality, impingement cooking, *Salmonella*, surface pasteurization

## 132 MICROBIAL GROWTH AT DIFFERENT STAGES OF TRADITIONAL AND MECHANICAL DEBONING

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Objectives: The study objective was to determine the microbiological impact of traditional and mechanical deboning on mesophilic aerobic plate counts for samples collected at different secondary processing locations in a commercial poultry processing facility.

Materials and Methods: Whole carcass and tenderloin part poultry rinses were collected at 3 different processing stages: whole carcasses without giblets, after deboning, and after antimicrobial intervention with a vinegar solution under either manual and mechanical deboning systems. At least 5 samples were collected at each stage to ensure different lot coverage, time of day effect, and microbial accumulation in the processing facility. The experiment was repeated during 3 different days to account for process variations that can be caused by operational and logistical issues in the plant. Microorganism levels were estimated at each sampling point using the TEMPO system. All data were log10 transformed before statistical analysis using R software (version 4.1.3).

Results: Mesophilic aerobic counts showed a significant difference between the 3 stages of sample collection as expected in a range of 1.5 to 5 Log CFU/ml ($P < 0.05$). There were significant differences in after-deboning ($P < 0.01$) and after-vinegar application ($P < 0.01$) between treatments, due to the greater manipulation in these two stages. During the processing chain, cross-contamination can occur and can influence the contamination levels of the whole production. However, the whole carcasses without giblets did not show statistical significant differences ($P > 0.05$) between treatments.

Conclusion: The microbial performance of the mechanical deboning system in this study indicates lower mesophilic aerobic plate counts when compared with the manual deboning systems. This project allows processors to elucidate the microbial load of their product through the processing line and supports the consideration of implementing enumeration schemes for statistical process control systems for shelf-life enhancement of finished product.

Keywords: deboning systems, mesophilic aerobic plate counts, poultry rinses, shelf life

## *133 ASSESSMENT OF ANTIMICROBIAL RESISTANCE IN VIBRIO AND ENTEROCOCCUS IN RETAIL SHRIMP MEAT IN NORTHERN CALIFORNIA*

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Objectives: Monitoring the prevalence and patterns of resistance in foodborne pathogens is critical to evaluate food safety and public health risks. This study characterized the antimicrobial resistance (AMR) of pathogenic non-cholera *Vibrio* spp. and *Enterococcus* spp., an indicator organism for gram-positive pathogens, found in shrimp sourced from grocery stores in Northern California.

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. Metadata associated with sample collection were also recorded. *Vibrio* and *Enterococcus* were isolated from samples based on the National Antimicrobial Resistance Monitoring System Retail Meat Surveillance Laboratory Protocol and Food and Drug Administration Bacteriological Analytical Manual. Suspected *Vibrio* spp. and *Enterococcus* spp. from culture were confirmed by polymerase chain reaction and Gram stain, respectively. Assessment of AMR pattern was performed with 110 samples each for *Vibrio* and *Enterococcus* isolates using minimum inhibitory concentration (MIC) analysis. Interpretation of resistance patterns (susceptible or resistant) for each antimicrobial agent was based on Centers for Disease Control and Prevention and US Department of Agriculture breakpoints (intermediate results were counted as resistant). Statistical analysis of results was performed using R and R-Studio. Fisher's exact test and its post hoc analyses were performed to determine significant differences in prevalence of AMR among the samples and between categories of metadata with $\alpha = 0.05$.

Results: *Vibrio* spp. were present in 60.25% of all samples (241/400). Of 110 *Vibrio* isolates analyzed with a 14-drug gram-negative MIC panel, 30.0% (33/110) exhibited multidrug resistance and 35.45% (39/110) were single drug resistant. No significant difference in resistance was found ($P = 0.82$) in *Vibrio* isolates from farm-raised shrimp (64.20%; 52/81) and wild-caught shrimp (69.0%; 20/29). Similarly, no significant difference was found ($P = 1$) when comparing prevalence of resistance between *Vibrio* isolates from domestically produced shrimp (68.42%; 13/19) and imported shrimp (64.84%; 59/91). *Vibrio* spp. did not exhibit exceptionally high levels of resistance to any specific drugs.

*Enterococcus* spp. were present in 89.75% of all samples (359/400). Of 110 *Enterococcus* isolates analyzed with a 16-drug gram-positive MIC panel, 97.27% (107/110) were multidrug resistant and 1.81% (2/110) were single drug resistant. There was no significant difference in resistance found ($P = 1$) in *Enterococcus* isolates from farm-raised shrimp (98.77%; 80/81) and wild-caught shrimp (100%; 29/29). Similarly, no significant difference was found ($P = 1$) in resistance prevalence between *Enterococcus* isolates from domestically produced shrimp (100%; 18/18) and

imported shrimp (98.91%; 91/92). *Enterococcus* isolates had especially high rates of resistance to quinupristin/dalfopristin (87.27%; 93/110) and lincomycin (96.36%; 106/110), both of which are prescribed to treat gram-positive infections in humans.

Conclusion: This study found that bacterial pathogens associated with shrimp sold in Northern California are highly resistant to some antimicrobial agents and that the patterns of resistance persisted irrespective of where or how the shrimp were produced. Notably, bacteria from farm-raised samples, many or all of which were likely exposed to antimicrobial agents during culture, did not exhibit higher rates of resistance than those from wild-caught samples.

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, *Enterococcus*, minimum inhibitory concentration, shrimp, *Vibrio*

## 134 ESTABLISHING PARAMETERS FOR THE DETECTION OF SALMONELLA USING DETECTX FOOD CHIP

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Objectives: The study objective was to evaluate the effect of incubation time and bacterial concentration on the detection of *Salmonella* in ground beef using Detect[x] microarray.

Materials and Methods: PathogenDx (PDx) detection system, Detect[x] microarray, is a newly designed real-time polymerase chain reaction (PCR) for the identification of microbial pathogens in food. In brief, the steps include sample preparation, DNA extraction, fluorescent labeling PCR amplification, and microarray hybridization. Ground beef samples of 94/6 lean/fat ratio were inoculated with 1, 5, 10, or 50 CFU/g of a *Salmonella* cocktail consisting of 5 different ATCC strains. Prior to sample preparation, 10 g of inoculated ground beef was enriched into 90 ml tryptic soy broth at 37°C for 6, 8, or 12 h. After enrichment, *Salmonella* was detected with the PDx system using a proprietary mix to target the *invA* gene. Following the company's protocol, samples were placed in a 96-well microarray plate in which ≥ 9,947 relative fluorescence units, as determined in a prior threshold study, were used to determine positive detection. The study was conducted in triplicate.

Results: Incubating samples for 6 h showed limitations to the system, as only the highest *Salmonella* concentration tested (50 CFU/g) was consistently detected in all samples. Considering all inoculum levels tested, the sensitivity of the system at 6 h incubation time was 25%. When samples were incubated for 8 h with an inoculum ≥ 5 CFU/g, the sensitivity reached 100%. However, 1 CFU/g was not accurately detected, with no samples showing true positives. At 12 h of enrichment, the microarray accurately detected *Salmonella* with a sensitivity of 100% at each inoculum concentration. Using a logistic regression model, a significant difference was found across all time points ($P = 0.007$). The odds ratio revealed that, with each hour increase in the incubation time, the ability to detect *Salmonella* increases 2.83 times. There was also a significant difference across bacterial concentrations ($P = 0.02$); thus, the odds ratio revealed that with each increase in concentration, the ability to detect *Salmonella* increases 1.73 times.

Conclusion: To achieve 100% sensitivity with the Detect[x] system, the incubation time should be not less than 8 h, if the bacterial concentration is ≥ 5 CFU/g in ground beef. Based on these preliminary results, the PDx PCR system could effectively be used as a high throughput detection tool throughout the beef industry to accurately detect *Salmonella* in ground beef, as an alternative to other commercially available detection systems. This study was intended to assess the parameters for detection of *Salmonella* using the current PDx PCR method. However, validation is recommended to prove sensitivity and specificity.

Keywords: ground beef, pathogen detection, polymerase chain reaction, *Salmonella*

## 135 ESCHERICHIA COLI AND SALMONELLA FROM FOOD-PRODUCING ANIMALS IN THE DOMINICAN REPUBLIC: MOLECULAR MARKERS AND PHENOTYPIC EXPRESSION OF ANTIBIOTIC RESISTANCE

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Objectives: The study objective was to identify discrepancies between genotypic-phenotypic expression antimicrobial resistance in *Escherichia coli* and *Salmonella* isolated from beef, swine, and poultry collected in the Dominican Republic.

Materials and Methods: Isolates ($n = 384$) were analyzed phenotypically using the Kirby-Bauer disk diffusion test evaluating resistance to 11 antibiotics and genotypically using Whole Genome Sequencing. Using a loop, 1 µl was streaked on Tryptic Soy Agar and incubated at 37°C for 24 h. Subsequently, one colony was inoculated in 9 ml of Tryptic Soy Broth and incubated at 37°C for 24 h. DNA was extracted using the GenElute bacterial

genomic DNA kit (Sigma-Aldrich, NA2100, NA2110, or NA2120, St Louis, MO) following the manufacturer's protocol, and Whole Genome Sequencing was performed using the Illumina NovaSeq-6000. Genome *de novo* assemblies were generated using shovill version 1.0.9 (v.1.0.9). Staramr 0.4.0 was used to screen assemblies for resistance determinants using the ResFinder database and PointFinder scheme for *Salmonella* spp. ARIBA v2.12.0 and the PointFinder database were used to screen *E. coli* for point mutations. Plasmid replicons were identified using abricate v.0.8.10 and a database adapted from PlasmidFinder.

Results: Genotypic-phenotypic association profile was made for 26 *E. coli* and 72 *Salmonella* isolates. Within the 26 *E. coli* isolates, 4 did not express phenotypic resistance to nalidixic acid or ciprofloxacin even when carrying *qnrB19, qnrS1*, or *parE (I355T)* determinants. Two *E. coli* isolates carried *tet(B)*, *tet(M)*, and *tet(C)* genes, but none showed phenotypic resistance to tetracycline. Moreover, one isolate carried *aadA2, aph(3")-Ib, qnrB19, blaTEM-1B, tet(B)*, and *tet(M)* genes, but no association between genotypic and phenotypic expression was found. On the other hand, *Salmonella* isolates presented a high consistency among serotypes. *S.* Meleagridis isolates carried *ac(2')-IIa* gene, but all of them were susceptible to streptomycin. The *parC(T57S)* point mutation was present in *S. Derby*, *S. Anatum*, *S. Johannesburg*, *S. Aberdeen*, *S. Muenchen*, *S. Agona*, *S. Cerro*, and *S. Uganda*; however, resistance to nalidixic acid and ciprofloxacin was not observed. Other *Salmonella* isolates, including *S. Meleagridis*, *S. Derby*, *S. Corvallis*, *S. Infantis*, and *S. Typhimurium*, exhibited azithromycin resistance, but genotypic antimicrobial determinants were not found. In addition, plasmid replicons were identified in the 98 bacterial isolates. The most frequent plasmid replicon in both, *E. coli* and S*almonella*, was Col (pHAD28) 46.1% (12/26) and Col(pHAD28) 34.7% (25/72), respectively.

Conclusion: Based on these findings, it is not uncommon to see phenotypic-genotypic disassociation as the presence or absence of resistance determinants do not always predict the phenotypic expression. This study provides a genotypic-phenotypic antimicrobial resistance profile in *E. coli* and *Salmonella* isolated from the environmental and retail meat samples in the Dominican Republic. There is minimal information available about the antimicrobial susceptibility patterns associated with foodborne pathogens found in this country. However, there have been reports of US citizens with gastrointestinal disease after traveling potentially acquired in this country.

Keywords: antimicrobial resistance, *Escherichia coli*, genotypic-phenotypic expression, plasmid replicon, *Salmonella*

## *136 THE EFFECT OF FASTING AND HYDROGEL BEAD SUPPLEMENTATION DURING TRANSPORT ON THE DYNAMICS OF SWINE MICROBIAL SHEDDING*

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Objectives: This study aimed to observe microbial shedding as affected by fasting and hydrogel bead supplementation. The specific objectives were to (1) evaluate changes in concentration of Enterobacteriaceae and *Escherichia coli* shedding due to fasting and transportation, (2) determine whether fasting and transportation affect the shedding of *Salmonella* and *E. coli* O157:H7, and (3) investigate the effect of hydrogel bead supplementation during transport on indicator organism and pathogen shedding.

Materials and Methods: To make the hydrogel beads, first a 2% sodium alginate solution was made by mixing 12 g of sodium alginate with 600 ml of distilled water. The solution was homogenized for 2 min using a blender. Then, a 10% calcium chloride solution was made by mixing 60 g of calcium chloride with 600 ml of an electrolyte solution. The calcium chloride solution was homogenized for 30 s using a blender. To test the effect of fasting and transportation, 60 market pigs were subjected to a 12-h fasting period and an additional 4-h transport period, in which a treatment group was fed hydrogel beads during transport and a control group was not. Sampling points were before fast, before transport, and after transport. Fecal samples were collected from every animal at each sampling point. Samples were processed, and indicator organisms were enumerated: Enterobacteriaceae and *E. coli* was performed on 3M™ Petrifilm. Additionally, prevalence *Salmonella* and *E. coli* O157:H7 was performed using the Real-Time BAX System.

Results: This study showed that there was a significant increase in the concentrations of both indicator microorganisms between the before-fast and after-transport sampling points only ($P < 0.05$). However, regarding the hydrogel beads, no difference ($P > 0.05$) was observed between the treatment (hydrogel) and control (no hydrogel) during transport. Moreover, no significant difference was found in the prevalence of *Salmonella* and *E. coli* O157:H7 at the 3 different sampling points, or between the treatment and control groups.

Conclusion: The combination of fasting and transportation led to an increase in concentrations of Enterobacteriaceae and *E. coli* in feces; however, no differences due to fasting and transportation were observed in the prevalence of *Salmonella* and *E. coli* O157:H7. Additionally, the supplementation of hydrogel beads did not lead to a significant change in concentrations of Enterobacteriaceae and *E. coli* in

**Table 2.** Effect of hydrogel on *Salmonella* and *E. coli* O157:H7.

| | Treatment[1] | | Control[2] | |
|---|---|---|---|---|
| | *Salmonella* | *E. coli* O157:H7 | *Salmonella* | *E. coli* O157:H7 |
| Positive[3] | 0/26 | 16/26 | 1/27 | 14/27 |
| Prevalence | 0.00% | 61.54% | 3.70% | 51.85% |

[1]Treatment animals supplemented with alginate hydrogel beads during transport.

[2]Control samples corresponded to animals with no access to beads during transportation.

[3]Positive results indicate the total of positives and the total samples analyzed. No difference ($p < 0.05$) was found between the control and the treatment group.

feces, nor was the prevalence of *Salmonella* and *E. coli* O157:H7changed.

Keywords: food safety, hydrogels, pathogen shedding, pork, swine

## 137 INHIBITION OF LISTERIA MONOCYTOGENES ON UNCURED READY-TO-EAT TURKEY STORED AT 4.4°C BY A FERMENT

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Objectives: High-moisture and high-pH uncured ready-to-eat (RTE) deli meats have been shown to support *Listeria monocytogenes* growth during refrigerated storage. Industry needs are pushing for longer shelf life of deli meats toward 130 d at 4.4°C. However, uncured formulation with high pH and low salt provides particular challenge to control *L. monocytogenes* for more than 90 d. The objective of this study was to evaluate the efficacy of a newly developed fermented ingredient (Cultured Sugar, DuraFresh Range) on the control of *L. monocytogenes* growth when inoculated onto uncured turkey breast deli meat, with concurrent assessment of indigenous spoilage microorganisms and product pH value over the course of the study (140 d for 4.4°C). Cultured sugar is a fermentation-based product that has various metabolites like different organic acids, small peptides, and residual sugars.

Materials and Methods: Five formulations of sliced, uncured, deli-style turkey were tested, including a no-antimicrobial control, and treatments with 1.21%, 1.36%, 1.52%, and 1.67% DuraFresh. Turkey breast, starch, carrageenan, brine (containing water, sea salt, and DuraFresh), and turkey trimmings were used to formulate treatments in 30-lb batches. Treatments were manufactured using fibrous casings to retain target analytical parameters. The amount of 100 ± 5 g of uncured turkey breast slices were surface inoculated with 0.5 ml of target 2–3 log CFU/g of a 5-strain *L. monocytogenes* cocktail (strains 101 [serotype 4b], 108 [1/2ab], 301 [1/2ab], 310 [4b], and FSL R2-500 [4b]), vacuum sealed in moisture and gas-impermeable bags, and stored at 4°C for up to 20 wk. Microbial populations were enumerated on rinse material obtained after soaking and massaging the contents of each package for about 2 min in 100 ml of sterile Butterfield's phosphate buffer. *L. monocytogenes* populations were determined from triplicate inoculated samples at time 0 and every 2 wk thereafter by surface plating on Modified Oxford agar (35°C, 48 h). Populations of lactic acid bacteria were determined via pour-plating of duplicate uninoculated samples using All-Purpose Tween agar with 0.04% bromocresol purple (25°C, 48 to 72 h). At each sampling point, changes in product odor and appearance (including notation for turbidity of package liquid) were monitored, and pH values measured in a 1:10 dilution of 10 g uninoculated sample with DI water. Time-to-growth was defined as the point at which growth reached ≥ 1 log CFU/g.

Results: Analytical values for treatments ranged from 73.9% to 76.5% moisture, 1.65% to 1.73% NaCl, 0.978 to 0.981 water activity, and pH 6.09 to pH 6.18. Growth of *L. monocytogenes* was observed in approximately 2.5 wk in the no-antimicrobial control, whereas growth was observed in approximately 15 wk in the 1.21% and 1.36% cultured sugar samples. *L. monocytogenes* growth was inhibited for > 20 wk in samples with 1.52% and 1.67% cultured sugar. No changes in pH, appearance, odor, or growth of lactic acid bacteria were observed in any of the uninoculated treatments throughout the study.

Conclusion: This work substantiates the antimicrobial performance of cultured sugar ferment against *L. monocytogenes* in RTE uncured turkey breast deli meat. The research provides the meat industry with a clean label solution for ensuring food safety of high-pH, low-salt RTE meat products for long refrigerated shelf life.

Keywords: antimicrobial, clean label, *Listeria*, spoilage, uncured

## 138 THE EFFECT OF A DIRECT-FED MICROBIAL (10-G) ON LIVE ANIMAL PERFORMANCE, CARCASS CHARACTERISTICS, AND SALMONELLA PREVALENCE OF FED BEEF HEIFERS

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Objectives: *Salmonella* is a naturally occurring bacteria causing upward of 1.35 million cases of foodborne illness annually. Cattle may harbor *Salmonella* in the gastrointestinal tract as well as in their lymph nodes. This creates a challenge because lymph nodes are impervious to post-harvest pathogen interventions, thus leading to potential contamination in ground beef production. Direct-fed microbials are a possible pre-harvest intervention to reduce the burden of *Salmonella*. The objective of this study was to determine the efficacy of a direct-fed microbial upon cattle and carcass performance, as well as prevalence and enumeration of *Salmonella* in feces and lymph nodes.

Materials and Methods: Fed beef heifers ($n = 1{,}400$; $343.3 \pm 36.2$ kg) were blocked by day of arrival and randomly allocated to one of 2 treatments (0 or 2 g/animal/d; CON and 10-G, respectively) with 10 pens per treatment. Cattle fed 10-G were provided 1 billion CFU per animal per day of *Lactobacillus acidophilus, Enterococcus faecium, Pediococcus pentosaceus, Lactobacillus brevis*, and *Lactobacillus plantarum.* Recto-anal mucosal swab samples (RAMS) and subiliac lymph nodes (SLN) were collected longitudinally at harvest from 24 heifers per pen ($n = 476$). Quantification of RAMS and SLN was completed via BAX *Salmonella* PCR assay following the SalQuant approach. Data were analyzed using the GLIMMIX procedure of SAS; pen served as the experimental unit, and block and harvest date were random effects.

Results: Heifers fed 10-G did not differ in dry matter intake ($P = 0.78$), final body weight ($P = 0.52$), average daily gain ($P = 0.49$), gain to feed ($P = 0.74$), hot carcass weight ($P = 0.56$), dressed carcass yield ($P = 0.83$), 12th rib fat depth ($P = 0.23$), ribeye area ($P = 0.62$), calculated empty body fat ($P = 0.35$), or marbling score ($P = 0.83$). Distributions of liver scores ($P > 0.14$), yield grade ($P > 0.22$), and quality grade ($P > 0.15$) were not different between treatments. We detected a tendency for fewer inflated lungs at harvest of cattle fed 10-G ($P = 0.10$; 10-G 0.2%, CON 1.0%); other lung outcomes did not differ ($P > 0.12$). *Salmonella* prevalence of RAMS samples did not differ ($P = 0.76$; 10-G 93.7%, CON 93.3%), nor did SLN ($P = 0.12$; 10-G 22.7%, CON 12.2%). *Salmonella* log of CFU/g of RAMS and SLN did not differ between treatments at harvest ($P = 0.49$; 10-G 3.78, CON 3.37; $P = 0.12$; 10-G 0.35, CON 0.08), respectively.

Conclusion: These results do not demonstrate any improvement in live animal performance, carcass characteristics, or reduction in *Salmonella*.

Keywords: cattle performance, direct-fed microbial, *Salmonella*

## *139 INFLUENCE OF CARCASS VASCULAR RINSING WITH BACTERIOPHAGE OR PERACETIC ACID ON MEAT QUALITY FROM SALMONELLA INOCULATED GOATS*

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Objectives: The study objective was to determine the effects of vascular rinsing carcasses with a solution containing bacteriophage (BP) or peracetic acid (PA) on meat quality from *Salmonella* inoculated goats.

Materials and Methods: The study was conducted over 4 different trial periods with cull dairy goats ($n = 60$). The goats consisted of various breeds (Alpine, Crossbred, Lamancha, Nubian, and Saanen), age (2 to 5 y) and live body weight ($74.5 \pm 13.7$ kg). Goats with similar characteristics were grouped together in sets of 3 before being randomly assigned to 3 treatments (TRT) that included: a control (CN; not vascularly rinsed) and two vascular rinse TRT using a Rinse & Chill process (RC; 98.5% water; balance: dextrose, phosphates, maltose). RC TRT included a BP (diluted PhageGuard S, $\sim 2 \times 10^{10}$ PFU/mL) added to the RC solution, and 2,000 ppm PA added RC solution. Animals were stunned by penetrating captive bolt. The RC TRT was applied to each carcass immediately upon exsanguination. Carcasses were skinned, eviscerated, surface sprayed with an antimicrobial (5% lactic acid), and refrigerated (2°C, 24 h). Decline in carcass temperature and pH were recorded (*semimembranosus* [SM]) at 1, 4, 8, and 24 h postmortem (PM). At 24 h PM, the *longissimus* (LM), SM, and *triceps brachii* (TB) were removed, cut into chops (2.5 cm thick), and packaged in an oxygen-permeable film. Color measurements (CIE $L^*$, CIE $a^*$, chemical states of myoglobin) were determined during storage (1, 4, 7 d) post fabrication. pH and expressible moisture were analyzed on a raw sample basis. Warner-Bratzler shear force (WBS) and cook loss (6 d post fabrication; at 68.3°C internal, SM and LM chops removed from oven) were also determined. Each animal served as the experimental unit. Data were statistically analyzed as factorial designs (TRT × decline, 3 × 4; TRT × storage time, 3 × 3) with a model that included trial period that served as a covariate.

Results: PA resulted in lower ($P < 0.05$) pH values than CN through 8 h PM. BP had lower ($P < 0.05$) pH values than CN at 4 and 24 h PM. PA chilled the carcass more quickly ($P < 0.05$) than CN at 4 and 8 h. TRT had no affect ($P > 0.05$) on lightness (CIE $L^*$). Chops became darker (CIE $L^*$, $P < 0.05$) by day 4 of display. BP chops (CIE $a^*$,

12.7) were more red ($P < 0.05$) than CN (CIE $a^*$, 12.1), whereas the PA chops were less red (CIE $a^*$, 12.4). TRT did not affect ($P > 0.05$) oxymyoglobin. BP LM chops had greater percentage deoxymyoglobin (DMb; $P < 0.05$; 7.7%) than CN (6.6%), and PA (3.9%) had the lowest percentage DMb. No TRT differences in DMB were found ($P > 0.05$) in the SM. PA had a greater ($P < 0.05$) percentage metmyoglobin (37.5%) than BP (35.7%) and CN (36.2%), which were not different from one another. Oxymyoglobin percentage and CIE $a^*$ decreased ($P < 0.05$) with display time. RC TRT were not different ($P > 0.05$) from CN in expressible moisture. In addition, RC TRT were not different ($P > 0.05$) from CN in cooking loss or WBS. SM had greater ($P < 0.05$, 23.2%) cooking loss than TB (21.0%). TB had lower ($P < 0.05$, 40.0 N) WBS than SM (54.1 N).

Conclusion: The effect of vascularly delivering antimicrobials throughout the vasculature on meat quality merits consideration as part of the assessment of the effectiveness of such applications to eliminate *Salmonella*. The meat quality trait most affected was color, which varied depending upon the antimicrobial treatment.

Funding Source: University of Wisconsin and MPSC Inc.

Keywords: bacteriophage, carcass vascular rinsing, goat, meat quality, peracetic acid

## 140 EVALUATION OF SEASONAL DIFFERENCES OF SALMONELLA SEROVARS WITHIN FEEDLOT ENVIRONMENTS

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Objectives: Persistent and long-term survival of *Salmonella* strains naturally present in the feedlot environment have the potential to affect cattle health and carcass yield, as well as food safety. In this study, *Salmonella* serovars present in environmental feedlot samples were identified using CRISPR-SeroSeq (serotyping by sequencing clustered regularly interspaced short palindromic repeats), a next-generation amplicon-based sequencing tool to define the relative frequency and identity of different *Salmonella* serovars.

Materials and Methods: Fecal, soil, and environmental samples ($N = 1{,}060$) were collected from 4 feedlots over 4 seasons (summer, fall, winter, and spring; $n = 58$ per season per feedlot). Samples were enriched in Rappaport-Vassiliadis (RV) and tetrathionate (TT) broths and streak plated for isolation on Xylose lysine tergitol 4 (a selective agar for *Salmonella*). Presumptive colonies were picked from plates and confirmed as positive *Salmonella* using BAX real-time *Salmonella* assay. Each positive *Salmonella* RV and TT mixed culture sample was preserved as a pellet. Total genomic DNA was extracted from the pellets to perform a two-step polymerase chain reaction procedure. In the first step, polymerase chain reaction amplified CRISPR regions, and the second step added Illumina index sequences to each pellet for multiplex sequencing. Analyzed samples were compared with a database composed of 135 unique *Salmonella* serovars to identify *Salmonella* spacer reads. The relative frequency of each serovar in the population was determined by the number of reads per spacer belonging to that serovar. Where samples were positive in TT and RV, CRISPR-SeroSeq data were combined into one sample for a total of 288 samples.

Results: *Salmonella* prevalence varied by season, with the greatest prevalence in summer and fall ($P < 0.01$). Throughout the seasons, a greater average number of *Salmonella* serovars were identified in the summer (2.8 serovars per sample) and fall (2.6), whereas the winter (2.1) and spring (1.6) had fewer serovars. Greater than one *Salmonella* serovar was present in 75.7% (218/288) of the samples, and one sample contained 10 different serovars. The most abundant serovars identified in this study were Anatum (69.8%), Montevideo (48.3%), Mbandaka/Lubbock (46.2%), and Muenchen (33.3%).

Conclusion: This study demonstrates that *Salmonella* in feedlot environments more often than not exists as complex mixtures of multiple serovars. The correlation between increased *Salmonella* prevalence and increased numbers of serovars in a sample warrants further investigation into the complexity of the *Salmonella* microbiome within a feedlot environment.

Funding Source: NCBA.

Keywords: CRISPR-SeroSeq, feedlot environment, prevalence, *Salmonella*, serovar

## 141 GROUND BEEF PATHOGEN DYNAMICS

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Objectives: Ground beef is a reservoir for both pathogenic and spoilage bacteria. Between April 2017 and March 2022, the US Department of Agriculture Food Safety and Inspection Service reported that over 13 million pounds of ground beef was recalled due to possible *Escherichia coli* O157:H7, *E. coli* O103, *E. coli* O26, *Salmonella* Dublin,

and *Salmonella* Newport. Similarly, a significant volume of ground beef is lost each year due to insufficient shelf life—which is largely driven by microbial deterioration. Managing the presence of pathogenic and spoilage bacteria in ground beef products is a notable priority for the industry. As tools to measure these variables evolve, it is imperative to explore potential avenues by which we can predict the presence of a pathogen or microbial spoilage. The objective of this study was to evaluate changes in the microbial community of raw ground beef throughout dark storage in the presence of a pathogen.

Materials and Methods: Fresh ground beef was equally divided into 2 batches for evaluation as a non-inoculated control, or inoculation with US Department of Agriculture Food Safety and Inspection Service–approved non-pathogenic *E. coli* surrogates (ATCC BAA-1427, BAA-1428, BAA-1429, BAA-1430, BAA-1431). Both control and inoculated ground beef samples were portioned and placed on expanded polystyrene trays before overwrap packaging. Overwrapped packages were placed into dark storage at 4°C. Samples were collected on days 0, 1, 2, 3, 5, and 7 for qualitative and quantitative evaluation of bacterial populations using traditional plate count methods and 16s rRNA sequencing. The project was replicated 3 times in a split-plot design, with replication and sample identification serving as random variables. Data analysis was performed using R.

Results: As anticipated, microbial populations changed in number and composition as dark storage length progressed. Although the inoculated packages had greater numbers of bacteria, the growth trend was similar to non-inoculated controls. Unexpectedly, naturally occurring rifampicin-resistant bacteria were observed in control samples, suggesting the acquisition of this resistance feature from other sources. Microbial populations within each group (Control and Inoculated) were largely influenced by inoculation but may be utilized to predict surrogate growth.

Conclusion: As microbial technologies evolve allowing for a more comprehensive examination of microbial populations, it is important to explore the relationship between pathogenic and non-pathogenic bacteria. Understanding the dynamic growth relationships between these two bacterial categories may yield valuable tools to predict the presence of pathogens or the onset of microbial spoilage.

Keywords: *Escherichia coli*, ground beef, microbiome, *Salmonella*

## 142 METABOLOMICS PROFILING OF MEAT EXUDATE TO IDENTIFY KEY METABOLITES IN RESPONSE TO SPOILAGE AND SALMONELLA INOCULATION

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Objectives: Spoilage and foodborne illness of muscle foods are the major food safety and waste challenges in the meat industry. Meat exudate contains water-soluble proteins and metabolites related to microbial biomass. Despite its potential as an excellent analytical matrix to determine meat spoilage and bacteria growth, no previous studies have evaluated the value of analyzing meat exudate for determining the extent meat spoilage and presence of foodborne bacteria in meat products. Therefore, the objective of this study was to characterize major compounds in meat exudate from fresh beef samples under meat spoilage and *Salmonella* challenged conditions using a metabolomics approach in 2 consecutive experiments.

Materials and Methods: In experiment 1, steaks (*m. longissimus lumborum*) from 6 beef carcasses (USDA Utility grade) were made, vacuum packaged, and assigned to either 4°C (control) or 10°C (spoilage) treatment for 2, 4, and 6 wk of aging in addition to day 0 (initial samples). In experiment 2, beef muscles (*longissimus lumborum* and *gluteus medius*) from 6 carcasses were ground together in 3 independent batches, divided into 350 g bags, and assigned to either control or *Salmonella* inoculation approximately 8 log CFU/mL. The samples were vacuum packaged and stored for 28 d at 4°C. Upon aging, exudate was collected, and metabolomics analysis was conducted using UPLC-ESI-MS system. In addition, total bacterial count, lactic acid bacterial count (LAC), and *Salmonella* count in meat and purge samples were measured. All data were analyzed using PROC GLIMMIX of SAS. Least-square means for all traits were separated (F test, $P < 0.05$) using PDIFF option.

Results: In experiment 1, 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 with 4°C storage ($P < 0.01$). TBC and LAC of exudate samples were significantly higher, indicating comparable purge sensitivity to muscle samples. The metabolomics analysis revealed 50 metabolites significantly responsive to spoilage, including peptides, amino acids, nucleotides, lipids, flavonoids, lactones, glutamic acid, and terpenoids ($P < 0.01$). In experiment 2, 29 major metabolites are strongly differentiated in the *Salmonella* inoculated group compared with control throughout the storage time ($P < 0.01$). Tentative putative biomarkers for the *Salmonella* inoculated group include terpene glycosides, glycerophospholipids, Alkyl aryl ethers, and lipids metabolites.

Conclusion: The results of this study found that metabolomics profiling of meat exudate clearly distinguished compounds from spoilage conditions (time and temperature) and *Salmonella* inoculation. In addition, changes in microbial counts in fresh meat during storage resulted in complex shifts in the metabolites present in meat exudate, indicating its potential as an excellent analytical medium. The results obtained in this study will provide novel insights on the

future development of rapid diagnostic tests for quality and safety control of spoilage and foodborne pathogens in meats.

Keywords: biomarker, meat exudate, metabolites, *Salmonella*, spoilage

## 143 CARCASS VASCULAR RINSING EFFECTS SUPPLEMENTED WITH BACTERIOPHAGE AND PERACETIC ACID ON SALMONELLA REDUCTION IN EXPERIMENTALLY INFECTED GOATS

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Objectives: The study objective was to determine the ability of carcass vascular rinsing supplemented with bacteriophage (BP) and peracetic acid (PA) to reduce *Salmonella* in lymph nodes (LN) from experimentally infected goats.

Materials and Methods: Cull dairy goats ($n = 60$) from various breeds (Alpine, LaMancha, Nubian, Saanen, and Crossbred), age (2 to 5 y), and live body weight (74.5 ± 13.7 kg) were grouped together in sets of 3 before being randomly assigned to a control (CN; not vascularly rinsed; $n = 20$) treatment and 2 vascular rinse treatments. A standard solution (98.5% water; balance: saccharides, phosphates; Rinse & Chill, MPSC Inc.) was used to deliver the vascular rinse treatments: BP (diluted PhageGuard S; $\sim 2 \times 10^{10}$ PFU/mL, $n = 20$) and PA (2,000 ppm PA, $n = 20$). Prior to slaughter and treatment application, a lancet was utilized intact (10LT; 10 surgical steel 1.2 mm lancet tips) or reduced to 3-lancet tips (3LT) to administer *Salmonella* Enteritidis (SE13) intradermally to the goats. The lancet was dipped into fresh *Salmonella* inoculum ($3.33 \pm 0.39 \times 10^8$ CFU/mL) and applied with light pressure (each leg with the 3LT, 13 applications: both anatomical sides of the caudal thorax near 12/13th thoracic vertebrae and ventral abdomen with the 10LT, 1 application). After an incubation period (7 d), goats were stunned with a penetrating captive bolt, and one Treatment was applied to each carcass upon exsanguination by inserting a catheter into the heart and rinsing the vasculature (10% of live weight). Carcasses were skinned, eviscerated, sprayed with an antimicrobial (5% lactic acid) and then chilled overnight (2°C). Carcass temperature and pH declines were recorded at 1, 4, 8, and 24 h postmortem. After chilling, superficial cervical, popliteal, medial iliac, and subiliac LN were collected and trimmed aseptically to remove non-lymphatic tissue prior to *Salmonella* enumeration and phage titer. Presumptive *Salmonella* colonies isolated from each LN were subjected the biochemical confirmation and spot assay for phage sensitivity. Each animal served as the experimental unit. A 3 × 4 factorial design (Treatment × LN) was used to statistically analyze the data, and trial period served as a covariate in the analysis.

Results: PA had lower ($P < 0.05$) carcass temperatures at 4 and 8 h postmortem (13.1°C and 6.8°C) than CN (16°C and 9.0°C) and BP (16°C and 10°C). PA had lower ($P < 0.05$) pH values through the first 8 h compared with CN. The lowest ($P < 0.05$) *Salmonella* load was in the medial iliac (2.7 ± 1.5 log CFU/g) compared with the other LN. PA reduced ($P < 0.05$) the *Salmonella* load (3.4 ± 1.3 log CFU/g) in the LN compared with CN (3.8 ± 1.1 log CFU/g). All *Salmonella* isolates collected from the LN were biochemically confirmed and were determined to be phage sensitive. Substantial phage titers were determined in the LN from BP (average 7.0 ± 0.91 log PFU/g, range: 4.8 to 8.7 log PFU/g). However, BP did not reduce *Salmonella* load compared with CN.

Conclusion: The *Salmonella* infection model was successful by providing sufficient counts to assess various carcass intervention methods regarding *Salmonella* counts and phage titer results. Vascular rinsing has potential to further reduce *Salmonella* in the LN if other antimicrobials, combinations of chemicals, and different concentrations are considered.

Funding Source: MPSC Inc.

Keywords: bacteriophage, lymph node, peracetic acid, *Salmonella*, vascular rinsing, goat carcasses

## 144 INTERVENTIONS TO IMPROVE CONTROL OF SALMONELLA DURING THE PRODUCTION OF ETHIOPIAN QWANTA

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Objectives: Qwanta is a homemade Ethiopian whole muscle dried beef product made utilizing an intricate cutting technique to create elongated, thin strips of meat that are seasoned and air dried at ambient temperatures. The relative risk of this preservation method is not well understood; it

does not utilize heat, and only modest amounts of salt (~1%) are used. Quantifying inherent risk and introducing available and culturally acceptable interventions may improve both availability and safety of animal-sourced foods in Ethiopia. Previously, we demonstrated a reduction in both *Escherichia coli* O157:H7 (3.5 ± 0.11 log CFU/g) and *Salmonella* (1.7 ± 0.23 log CFU/g) during drying, although with opportunity for improvement. The objective of the current study was to evaluate interventions during qwanta production to further mitigate the risks of foodborne diseases.

Materials and Methods: Qwanta strips (20 ± 5.0 g) were cut from the top round (< 2% fat), inoculated with 5 serotypes of *Salmonella enterica* (Anatum, Dublin, Newport, Saintpaul, Typhimirium), and either dipped in vinegar, wine, or 0.9% saline (control). Strips were allowed to drip-dry for 10 min before being seasoned with a mixture of salt (1%) and Berbere (1.5%; an Ethiopian spice). Strips were placed in ambient air-drying chambers with air circulation (2600 exchanges/h) for 0, 1, 4, and 7 d post inoculation, weighed, and plated for enumeration. Two independent replicates of each trial were conducted. Data were log transformed and analyzed using version 16.1.0 of JMP Pro. A nonlinear Weibull model was used to fit *Salmonella* inactivation data displaying a downward concaving curve indicating a presence of a shoulder, using version 1.4.1717 of RStudio.

Results: A nonlinear predictive model was fitted to the inactivation data revealing a downward sloping curve for the inactivation of *Salmonella*. The predictive model for control and wine samples show a nearly 3-d drying period (3.12 ± 0.71 and 2.86 ± 0.62 d, respectively) to achieve the first log inactivation of *Salmonella* and a day (1.23 ± 0.34 d) of drying for the vinegar samples. Final weight loss was not affected by treatment ($P > 0.28$); however, qwanta lost ($P < 0.0001$) 56.5%, 65.7%, and 66.2% of weight on day 1, 4, and 7, respectively, compared with day 0. All treatments achieved $a_w < 0.57$ after 7 d of drying. Control and wine treatments resulted in a 1.9 ± 0.12 log CFU/g reduction in *S. enterica* by day 7 ($P < 0.0001$). Vinegar showed increased ($P < 0.0001$) inactivation of *S. enterica* (2.7 ± 0.12 log CFU/g) compared with the control group.

Conclusion: During the drying of Ethiopian qwanta, there is limited inactivation of *Salmonella*, likely attributed to desiccation tolerance. The inclusion of vinegar significantly increases pathogen inactivation and could be a viable intervention during the production of qwanta. Additional sensory testing should be utilized to ensure that the inclusion of vinegar does not affect the desired taste of Ethiopian qwanta.

Funding Source: Bill and Melinda Gates Foundation and UK Foreign, Commonwealth & Development Office.

Keywords: dehydration, dried beef, international development, intervention, risk mitigation

## *145 LEVERAGING THE SYNERGISTIC EFFECT OF ORGANIC ACIDS WITH MILD HIGH PRESSURE PROCESSING (HPP) TO REDUCE SALMONELLA SPP. IN PORK TRIM*

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Objectives: Pork processors often use organic acids to mitigate cross-contamination and decontaminate surfaces. Additional microbial reductions may be achieved if the use of organic acids is coupled with a mild high pressure processing (HPP) treatment. The objective of this study was to evaluate the effect of combining mild HPP treatment (300 MPa for 3 min) with organic acids on the reduction of *Salmonella* spp., meat color, and pH of raw pork trim.

Materials and Methods: Pork trim samples (20% fat) were tempered and portioned into 20 ± 5 g sample strips and kept frozen until testing. Samples were thawed, inoculated with a five-strain cocktail of *Salmonella* spp., and left at room temperature for at least 1 h for proper bacterial attachment prior to dipping for 30 s in distilled water (Control) or one of the following organic acids: (a) lactic acid (LA), 4%; (b) acetic acid (AA), 4%; (c) citric acid (CA), 4%; and (d) peroxyacetic acid (PAA), 400 ppm. Afterward, half the samples were treated with HPP at 300 MPa for 3 min, and the other half were not. *Salmonella* counts were enumerated using a thin agar layer of xylose lysine deoxycholate topped with tryptic soy agar at the following timepoints: a) Day 0, 1.25 ± 0.25 h after dipping, (b) Day 1 or 24 h post dipping, (c) Day 2 or 24 h post HPP, and (d) Day 7 post inoculation. All microbial counts were reported on a logarithmic ($\log_{10}$) scale. A second set of non-inoculated samples were prepared and treated in a similar manner and timepoints for pH and color analyses. Changes (D) in meat color and pH and were calculated against samples dipped in distilled water that had not treated with pressure. The experiment was as a split-split plot design, in which pressure treatment served as the whole plot unit, split by organic acid treatment, and further split by sampling timepoint. The experiment was conducted as a randomized complete block design with 3 replications, and each replication was a blocking factor and represented one biological and one technical replication.

Results: Acid treatment reduced *Salmonella* populations by 0.4 to 1.50 log, whereas mild HPP treatment yielded 1.75 to 2.03 log reductions. When acids and mild HPP treatments were combined, reductions drastically increased to 2.08 to 4.74 log, demonstrating synergistic effects for LA, CA, and AA. Log reductions from 400 ppm PAA and mild HPP were not significantly different from distilled water and mild HPP. The use of acids significantly ($P < 0.05$)

increased brightness (higher $\Delta L^*$) and yellowness (higher $\Delta b^*$) of pork trim. No differences in pH changes were found across all treatments.

Conclusion: The combination of dipping pork trim in LA, CA, and AA and mild HPP worked synergistically to reduce *Salmonella* by as much as 1.3 to 2.0 log over the sum of the individual treatments. Meat pH and color from the combined treatments were not significantly different from dipping in acid alone.

Keywords: None

## 146 IMPROVING THE SHELF LIFE AND SAFETY OF KUNDI, A NIGERIA INTERMEDIATE-MOISTURE MEAT

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Objectives: Preserved smoked-dried meat product kundi (a ready-to-cook meat) in Nigeria, which is mainly consumed by low-income earners as their main source of protein, has a shelf life of less than 2 wk before onset of fungi growth. Often retailers prolong its shelf life to about a year by rubbing used vegetable oil on its surfaces, inversely introducing more microbes to the products. This study focuses on the use of natural preservatives to extend the shelf life of kundi products.

Materials and Methods: Twenty kilograms of thigh muscle of White Fulani animal was purchased from Teaching and Research Farm; processed by trimming off all external fat, blood vessels, and excess epimysia connective tissues; and deboned, washed, and cut into 70 to 90 g of 6 cm to 8 cm width. Meat was divided into 7 treatments of 60 pieces of meat, with 3 replicates of 20 pieces of meat each. Samples were boiled at 100°C for 20 min, and boiled samples were marinated for 24 h with 6 natural preservatives and kept in a refrigerator for 24 h, grouped as follows: T1 Control, T2 Apple Cider Vinegar, T3 Chili Pepper, T4 Garlic, T5 Honey, T6 Lemon Juice, and T7 Sugar Solution. After this, they were later smoked-dried to kundi, for 3 h at 250°C to 300°C to evaluate the physicochemical characteristics, proximate and mineral composition, lipid oxidation, and microbial count; they were evaluated for every 2-wk interval for a duration of 8 wk of storage, and palatability scores were evaluated using a completely randomized designed, with SAS computer software, at a $P < 0.05$ probability level.

Results: Results shows that, for boiled marinated beef, T2 and T6 had the highest ($P < 0.05$) significant protein and mineral composition and the lowest ($P < 0.05$) extract, lipid oxidation, and microbial counts compared with other treatments. At 8 wk of storage, T2 had the highest significant ($P < 0.05$) nutrients in terms of proximate and mineral composition compared with other treatments for lipid oxidation and microbial counts. T2 and T5 had the lowest significant ($P < 0.05$) values of 14.95 ngmDA/g and 11.90 ngmDA/g lipid oxidation, respectively, and microbial loads of $5.60 \times 10^5$ CFU Total Bacteria Count, $4.35 \times 10^3$ Total Fungai Count, and $4.35 \times 10^1$ Total Coliform Count, compared with other treatments evaluated. The panelist's score TI (7.80) ($P < 0.05$) higher whereas T2 had the least score (3.60) with a 9 hedonic scale.

Conclusion: The addition of apple cider vinegar (T2) into kundi production in Nigeria, with a standardized amount per kilogram of meat, could improve its shelf life, minimize microbial load for consumer safety, and increase its acceptability to the populace.

Funding Source: Self-funded.

Keywords: kundi, garlic powder, lemon juice, pure honey, apple cider vinegar, chili pepper

## 147 LISTERIA PHAGES HELP TO REDUCE LISTERIA ON PEELED HARD-BOILED EGGS

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Objectives: Many common ready-to-eat (RTE) foods can be sources for *Listeria* infection, called listeriosis. This is due to contamination of the food products with the pathogenic bacterium *Listeria monocytogenes*. Listeriosis is deemed a serious foodborne disease due to its high hospitalization and fatality rates. In the Unites States alone, there are ~1,600 listeriosis cases per year. In 2017, a *Listeria* outbreak was linked to hard-boiled eggs. A Food and Drug Administration (FDA) inspection of the hard-boiled egg processing plant showed that *L. monocytogenes* was confirmed present on food contact and environmental surfaces. Current Good Manufacturing Practice and Preventive Controls rules by the FDA encourage manufacturers that process, pack, and hold RTE foods to have a food safety plan to help significantly minimize hazards such as *Listeria* in RTE products. Bacteriophage (phage) technology is an attractive new alternative for food safety intervention to use for RTE food processors. Phages provide a targeted kill of pathogenic bacteria. *Listeria* phage products are natural, organic, and easy to apply. They do not affect sensory qualities or require labelling on the food, as it is regarded as a processing aid by the FDA. Phages are not harmful for employees or processing equipment. Therefore, this study assesses whether a commercially available, *Listeria*-specific,

bacteriophage product (PhageGuard Listex) can kill *Listeria* on the surface of hard-boiled eggs.

Materials and Methods: Raw eggs were boiled, cooled to room temperature, peeled, and subsequently contaminated with $2 \times 10^4$ CFU/g *L. monocytogenes* by applying 0.2 µL/g of culture. Even distribution of the inoculum was checked with a food coloring dye on the surface of the egg. The phage product was diluted in tap water to either a high (0.2%, $10^7$ PFU/cm$^2$) or low (0.1% and $5 \times 10^6$ PFU/cm$^2$) concentration, after which 1.5 mL of either solution was evenly dropped on the surface of the inoculated eggs. The run-off phage solution was collected in the plastic bag used to store the eggs after treatment. Control samples were treated with tap water. Treated samples were stored at 4°C (39°F) until *Listeria* enumeration at 0, 3, 6, and 24 h post treatment. The data presented are mean values of 3 individual experiments, analyzed with a two-way ANOVA (Sidak's multiple comparisons test).

Results: *Listeria* was reduced significantly on the surface of hard-boiled eggs treated with bacteriophages, when compared with water treated controls. Treatment with a 0.2% phage solution resulted in a 1.3 log ($P < 0.0001$) reduction of *Listeria* after a dwell time of 3 h and a maximum kill of 2.2 log ($P < 0.0001$) after 24 h. The 0.1% phage solution provided a 1.0 log ($P < 0.0001$) kill after 6 h and a maximum *Listeria* reduction of 1.9 log ($P < 0.0001$) after 24 h.

Conclusion: Recent recalls (2017–2020) show that the hard-boiled egg production environment poses hazards after peeling. We show here that treating the peeled boiled eggs before packaging with an anti-*Listeria* bacteriophage solution, through a dip or spray application, provides an effective way of killing *Listeria* on hard-boiled eggs.

Keywords: food safety, phages, *Listeria*, hard-boiled eggs, ready-to-eat

## *148 EFFECT OF CARCASS DECONTAMINATION ON RECOVERY OF CHRYSEOBACTERIUM SPECIES FROM CHICKEN CARCASSES*

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Objectives: The most widely used antimicrobial intervention in the poultry industry is the use of chlorine-based antimicrobial washes (Killenger et al., 2010). *Chryseobacterium* spp. are known for their ability to spoil food due to their production of proteolytic enzymes and their psychrophilic nature (Bernadet et al., 1996). In recent studies, this organism was isolated from freshly slaughtered chicken (Oosthuizen, 2019) and can survive chlorine wash treatments. Our objective was to compare various antimicrobial rinses of poultry carcasses at harvest to determine the effect on various spoilage organisms.

Materials and Methods: We obtained untreated freshly slaughtered chicken carcasses from a small abattoir in Versailles, Missouri, and 18 carcasses were randomly assigned to each treatment protocol: 30 s wash in 2% lactic acid, 50 ppm chlorine or drinking water (control). Each carcass was swabbed before any treatment to assess original bacterial load. The chicken breasts were quartered, weighed, tray-wrapped individually, and stored at 4°C until the microbial content was assessed on day 1, 3, and 6. The study was repeated in triplicate as an RCBD with a total sample size of 54 chickens. The microbial analysis included total aerobic bacterial count, the total coliform count, and the total lactic acid bacteria (LAB) present in the samples using a combination of standard practices and Petrifilm (Types AC, CC, and LAB). A pour plate method was used to count *Pseudomonas* spp. and provide colonies for *Chryseobacterium* isolation.

Results: The lactic acid treatment reduced the AC, CC, and LAB counts at each time interval, but the differences were not statistically significant ($P > 0.05$). The coliform count was acceptable (100 to 1,000 CFU/mL), but they should be below 100 CFU/mL for fresh meat. LAB counts averaged 3.14 and 3.10 log CFU/mL for control and chlorine treatments, and this is an indicator that they generally survive chlorine treatments. We were unable to identify the species *Chryseobacterium* from any of the chicken breast samples. They may not be present in the specific poultry setting we tested, or sampling methods needed to be amended to isolate the bacterial strains. The total bacterial counts prior to decontamination treatment averaged 3.55 ± 0.28 log CFU/mL, but a different recovery method (swab vs. stomacher method) was used. The shrinkage of the chicken breast portions during storage averaged 3.5% to 5.0% (± 3.02%) and was not affected ($P > 0.05$) by type of decontamination treatments.

Conclusion: Although we were not able to identify *Chryseobacterium* from any carcasses, the lactic acid rinse

**Table 1.** Effect of antibacterial treatment and storage time on bacterial counts of chicken carcasses

| | Total aerobic count (log cfu/ml) | | | Total coliform count (log cfu/ml) | | |
|---|---|---|---|---|---|---|
| Treatment | Day 1 | Day 3 | Day 6 | Day 1 | Day 3 | Day 6 |
| Control | 3.91 ± 0.3 | 3.95 ± 0.39 | 4.12 ± 0.21 | 2.09 ± 0.99 | 1.93 ± 0.96 | 2.08 ± 1.09 |
| Lactic acid | 3.47 ± 0.45 | 3.21 ± 0.41 | 3.21 ± 0.48 | 1.92 ± 0.96 | 1.15 ± 0.61 | 1.28 ± 0.64 |
| Chlorine | 3.95 ± 0.32 | 4.02 ± 0.21 | 4.32 ± 0.52 | 2.23 ± 1.06 | 1.84 ± 0.91 | 1.81 ± 0.99 |

was shown to be a promising treatment for reducing bacterial counts, including coliforms and LAB, on chicken breast surfaces.

Funding Source: Food Science Department, University of Missouri.

Keywords: chicken carcass, *Chryseobacterium* spp., lactic acid

## 149 EFFECTIVENESS OF PERACETIC ACID AS A SHORT-DURATION ANTIMICROBIAL SPRAY TO MITIGATE SALMONELLA SPP. AND CAMPYLOBACTER JEJUNI WHILE NOT DISRUPTING THE MICROBIOTA OF INOCULATED POULTRY THIGHS

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Objectives: With peracetic acid (PAA) being widely utilized during poultry processing as a means to reduce pathogen prevalence, little is known about its impact on the microbiome of poultry carcasses. Therefore, when investigating the impacts of differing PAA formulations on pathogen reduction, it also is important to simultaneously determine the direct influence PAA has on the microbiota composition. Thus, the objective of the current study was to determine the impact of a commercial PAA, when used as a short-duration antimicrobial spray (15-s), on the microbiota of poultry thighs inoculated with *Salmonella* spp. and *Campylobacter jejuni.*

Materials and Methods: Poultry thighs ($N = 25$, $n = 5$, $k = 5$) were inoculated with a cocktail of *S.* Typhimurium (S-9), Heidelberg (S-13), Enteritidis (E-40), Infantis (6424), Kentucky (M-09-0001A-1) and *C. jejuni* (NCTC) at $10^8$ CFU/mL and incubated at 4°C for 60 to 90 min for a total attachment of $10^7$ and $10^5$ CFU/g of *Salmonella* spp. and *C. jejuni*, respectively. Inoculated thighs (~100 g) were either not treated or independently sprayed in a modified spray cabinet for 15 s with one of the following treatments: tap water or 200, 400, or 800 ppm of PAA. Samples were allowed to rest for 2 min following treatment and were rinsed in 150 mL of neutralizing buffered peptone water for 1 min. Subsequent rinsates were utilized for pathogen detection and microbiota analyses. *Salmonella* and *C. jejuni* were enumerated by spread plating 100 µL on either XLD or mCCDA agar. Genomic DNA of homogenates was extracted using Qiagen DNeasy Blood and Tissue kit, and the 16S recombinant DNA was sequenced on an Illumina MiSeq. Pathogen data were analyzed using linear regression and one-way ANOVA in R Studio, with means separated by Tukey's protected HSD ($P \leq 0.05$). Microbiota data were filtered and aligned using the QIIME 2-2021.11 pipeline, with data considered significant at $P \leq 0.05$ for main effects and $Q \leq 0.05$ for pairwise differences.

Results: The results of the study demonstrated that short-term exposure to PAA was effective at reducing inoculated *Salmonella* and *Campylobacter* (0.3 to 1.1 and 0.6 to 1.5 $\log_{10}$ CFU/g, respectively) compared with the no-treatment control ($P < 0.05$). As the concentration of PAA increased, pathogens were reduced with 800 ppm PAA being the most effective (linear fit, $P < 0.05$, $R^2 = 0.47$ and 0.58). In addition, there were no significant effects of treatment on the alpha and beta diversity metrics or on the microbiota composition when using the analysis of composition of microbiomes ($P > 0.05$, $Q > 0.05$). The inoculated microbiota composition was largely composed of Gammaproteobacteria and Campylobacteria, which constituted over 65% and 5% of the microbiota at the class level, respectively.

Conclusion: Overall, 800 ppm PAA using a short-duration spray was the most effective at reducing *Salmonella* spp. and *C. jejuni* without negatively impacting the microbiota composition of inoculated poultry thighs.

Funding Source: The funding for this project was provided by Hydrite Chemical Company.

Keywords: 16S recombinant DNA, *Campylobacter*, peracetic acid, poultry, *Salmonella*

## 150 ANTIMICROBIAL ACTIVITY OF PERACETIC ACID, CULTURED DEXTROSE FERMENTATE, AND BUFFERED VINEGAR ON SALMONELLA AND AEROBIC BACTERIA IN RAW CHICKEN LIVERS

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Objectives: Chicken livers are increasingly being used as ingredients in human and animal products. *Salmonella* remains a concern in raw poultry products, where undercooking and cross contamination may lead to illness. Therefore, exploring alternatives to minimize risk is critical. This study aimed to evaluate the use of peracetic acid (PAA), cultured dextrose fermentate (CDF), and buffered vinegar (BV) in reducing *Salmonella* and aerobic bacteria in raw chicken livers.

Materials and Methods: Chicken livers were inoculated with a five-strain cocktail of poultry-borne *Salmonella* to obtain $10^6$ CFU/g. Samples were air-dried for 20 min and placed at 4°C for another 24 h to allow further microbial attachment. Samples were immersed for 90 s with agitation (40 rpm) in one of the following treatments: distilled

water (control), 450 ppm PAA, 1.5% CDF, and 2.0% BV. Treated samples were individually vacuum-packed, stored at 4°C, and analyzed for *Salmonella*. A separate set of uninoculated chicken livers were subjected on the same treatments to measure aerobic plate count. Samples were aseptically removed from their packaging on days 0, 3, 7, and 14. Chicken livers were then placed in a sterile stomacher bag, to which 0.1% buffered peptone water was added to prepare a 1:10 dilution. Samples were stomached for 90 s at 200 rpm and plated on XLD agar and 3M Petrifilm for *Salmonella* and aerobic plate count, respectively. Three independent replications were performed with 2 subsamples for each treatment and timepoint. Data were analyzed using analysis of covariance with treatment and time as independent variables, replications as block, and weight as covariate. Color measurement was also obtained using a handheld portable colorimeter (Model BC-10, Minolta Camera Co Ltd., Osaka, Japan) on days 0, 1, 3, 7, and 14, and expressed as CIE $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness).

Results: PAA resulted in the highest log reduction at $0.65 \pm 0.12$ although there were no significant differences in the reductions for any treatments ($P > 0.05$). After 14 d, higher reductions were still observed for PAA, but the difference was only seen when compared with CDF and not with BV or the control. Although similar reductions ($P > 0.05$) were noted after 14 d except for CDF, *Salmonella* population was lowest at all timepoints when PAA was used. All antimicrobial treatments demonstrated control in the growth of aerobic bacteria as PAA, and CDF were able to slow down growth rate until the 3rd day and BV until the 7th day of storage. As for color, there was a difference observed in lightness ($L^*$) for PAA, but this was only reflected on the day of treatment until the 1st day of storage. No differences in in $L^*$, $a^*$, and $b^*$ were noted from day 3 to day 14 of storage, implying that color will be less of a concern once the chicken livers are purchased and reaches the consumers.

Conclusion: Immersion in different antimicrobial agents has the same effect with distilled water in reducing *Salmonella*. BV is the most effective treatment in extending the shelf life of raw chicken livers. Synergistic effects of PAA and BV could be further explored in chicken livers and other variety meats.

Keywords: decontamination, pet food, *Salmonella*, variety meats

## 151 APPLICATION OF A SHORT-TERM PERACETIC ACID SPRAY ON INOCULATED BEEF TRIM REDUCES KEY FOODBORNE PATHOGENS WITHOUT CHANGING THE OVERALL MICROBIOTA COMPOSITION

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Objectives: For antimicrobial interventions to be utilized effectively in meat processing, it is essential to understand the effect these interventions have on foodborne pathogens and the subsequent microbiota of red-meat carcasses. Therefore, the objective of this study was to determine the influence of peracetic acid (PAA) used as a short-term antimicrobial spray on the microbiota of beef trim inoculated with *Salmonella* spp. and *Escherichia coli* serovars.

Materials and Methods: Beef trim ($N = 25$, $n = 5$, $k = 5$) were inoculated with a cocktail of *S.* Typhimurium (S-9), Heidelberg (S-13), Enteritidis (E-40), Infantis (6424), Kentucky (M-09-0001A-1) and *E. coli* serovars (026:H11, 111:H8, 0103:H2, 045:H2, 0145:NM, 0121:H19, 0157:H7) at $10^8$ CFU/mL and incubated at 4°C for 60 to 90 min for a total attachment of $10^7$ CFU/g. Inoculated trims (100 g) were either not treated or independently sprayed in a modified spray cabinet for 10 s with one of the following treatments: tap water or 200, 400, or 800 ppm of PAA. Samples were allowed to rest for 2 min following treatment. Trim samples were rinsed in 100 mL of DE Neutralizing Buffer and stomached for 1 min at 120 rpm. Subsequent homogenates were utilized for pathogen detection and microbiota analyses. *Salmonella* and *E. coli* were enumerated by spread plating 100 µL on either XLD or MacConkey agar. Genomic DNA of homogenates was extracted using Qiagen DNeasy Blood and Tissue kit, and the 16S recombinant DNA was sequenced (Illumina MiSeq platform). Pathogen data were analyzed using linear regression and one-way ANOVA in R Studio, with means separated by Tukey's Protected HSD ($P \leq 0.05$). Microbiota data were filtered and aligned using the QIIME2-2021.11 pipeline, with data considered significant at $P \leq 0.05$ for main effects and $Q \leq 0.05$ for pairwise differences.

Results: The results of the study demonstrated that short-term exposure to PAA was effective at reducing inoculated *Salmonella* and *E. coli* by 0.5 to 0.8 and 0.5 to 0.7 $\log_{10}$ CFU/g, respectively, compared with the no-treatment control ($P < 0.05$). As the concentration of PAA increased, pathogens were reduced (linear fit, $P < 0.05$, $R^2 = 0.22$ and 0.21). In addition, there were no significant effects of treatment on the alpha and beta diversity or microbiota composition of the trim homogenates ($P > 0.05$, $Q > 0.05$). Among the beef trim samples, the microbiota composition was largely composed of Enterobacteraceae (family), which constituted over 80% of the microbiota. *Campylobacter* (genus), *Brachybacterium* (genus), *Brevibacterium* (genus), Aerococcaceae (family), and *Corynebacterium* (genus) were also identified.

Conclusion: Overall, PAA using a short duration spray was effective at reducing *Salmonella* and *E. coli* without altering the microbiota composition of inoculated beef trim.

Funding Source: Funding for this project was provided by Hydrite Chemical Company.

Keywords: 16S recombinant DNA, beef trim, peracetic acid, *Salmonella*, Shiga toxin–producing *E. coli*

### *152 BIO-MAPPING OF INDICATOR BACTERIA ON SIX TRIMMED AND UNTRIMMED HOT AND COLD BEEF CARCASS AREAS*

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Objectives: The purpose of this study was to determine the effect of lipid tissue on bacterial levels by evaluating the total aerobic plate counts (APC) for trimmed and untrimmed carcasses sampled at 6 different carcass areas before and after chilling.

Materials and Methods: Cattle ($N = 20$ animals) were harvested at the Gordon Davis Meat Laboratory at Texas Tech University. Each carcass was treated independently as an experimental unit. After each animal was split into 2 halves, each half was randomly assigned to either trimmed or untrimmed treatment alternating left and right sides. On trimmed carcasses, subcutaneous fat was removed completely, whereas in untrimmed carcasses, the fat layer was left intact. Samples were taken at 6 different carcass areas including Round, Loin, Rib, Chuck, Brisket, and Flank. Sample collection was performed using EZ-Reach swabs pre-hydrated with 25 mL of buffered peptone water to collect a 100 $cm^2$ area on untrimmed (control) and trimmed carcasses. Each repetition ($n = 120$) consisted of a total of 60 samples per trimmed/untrimmed treatment with 10 samples per carcass area. Carcasses sampled before chilling were sprayed with lactic acid (2%–5%) and moved to the chiller. After chilling carcass sample collection was conducted 24 h after completing the cooling process for both treatments. Swab samples were immediately chilled and transported to the International Center for Food Industry Excellence Food Microbiology Laboratory at Texas Tech University for microbial analysis. Samples were stomached at 230 rpm for 1 min and then serially diluted as needed using 9 mL buffered peptone water tubes. Each swab/dilution was treated as an independent sample for quantitative testing using the Tempo System for Aerobic Counts. A total of 2 repetitions ($n = 480$) were conducted throughout the whole study. Counts were log10 transformed and statistically analyzed using R (version 4.04).

Results: For each untrimmed sampling area, APC were significantly reduced ($P < 0.001$) in Round, Loin, Chuck, Brisket, Rib, and Flank on average by 1.23, 1.10, 0.95, 1.06, 1.20, and 1.84 Log CFU/$cm^2$, respectively, by the lactic acid intervention and chilling process. Similar results were observed for trimmed samples: for Round, Loin, Chuck, Brisket, Rib, and Flank, the APC were significantly reduced on average by 0.74, 1.00, 0.98, 1.03, 0.94, and 1.06 Log CFU/$cm^2$, respectively. No differences were observed when comparing trimmed versus untrimmed carcass samples either before or after chilling.

Conclusion: There was no significant difference among treatments (trimmed and untrimmed samples). However, as expected significant reductions were observed in APC when comparing before and after chilling carcasses in all 6 different carcass areas, considering the lactic acid application in all samples before chilling.

Keywords: aerobic plate counts, carcass mapping, hot carcass, lactic acid

## Muscle and Lipid Biology and Biochemistry

### *153 EVALUATION OF USING IMMUNOBLOTTING TO DETERMINE BOVINE MYOSIN HEAVY CHAIN ISOFORMS AND THEIR CONTRIBUTION ON THE EATING QUALITY OF 11 DIFFERENT BEEF MUSCLES*

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Objectives: The relationship among muscle fiber types and beef quality has been heavily researched, but the exact relationship has yet to be fully established. This is largely because the traditional immunohistochemical process of determining muscle fiber type is labor intensive, thus creating sample size limitations. Therefore, the objective of this study was to establish a more efficient immunoblotting procedure to determine muscle fiber types and the contribution of muscle fiber type on the eating quality of 11 different beef muscles.

Materials and Methods: Eleven different beef muscles were utilized from 2 separate studies. In study 1, *triceps brachii* (TB), *rectus abdominus* (RA), *rectus femoris* (RF), *supraspinatus* (SS), *gluteus medius* (GM), *pectoralis profundi* (PP), *semitendinosus* (ST), and *longissimus thoracis* (LT) were collected from 10 USDA choice carcasses ($n = 80$). In study 2, *longissimus lumborum*, *tensor fascia latae* (TF), and *gastrocnemius* (GC) were collected from

10 USDA Low Choice carcasses ($n = 30$). Myofibrillar proteins were extracted from each sample, separated by gel electrophoresis, and immunoblot against 4 primary antibodies that recognize 1) all myosin heavy chain isoforms; 2) type I only; 3) type 2X only; or 4) type 2A only. Relative percentage of each fiber type was calculated by normalizing the intensity of each specific isoform against the intensity of all myosin heavy chain isoforms. Pearson correlation analysis was conducted to determine the relationship between muscle fiber type and the eating quality of beef that was previously reported in Chun et al. (2020) and Hammond et al. (2021).

Results: In study 1, RA and SS had the greatest relative percentage of type I fibers, followed by TB and GM, with PP, LT, RF, and ST having the lowest ($P < 0.01$). On the other hand, ST, LT, and RF had the greatest relative percentage of type 2A fibers, followed by GM, PP, and TB, with SS and RA having the least ($P < 0.01$). However, there was only a tendency for differences in relative percentage of type 2X fibers among the muscles ($P = 0.08$). In study 2, there was no difference between the relative percentage of type I fibers ($P > 0.05$). LN had greater relative percentage of type 2A fibers than both TF and GC ($P < 0.05$). Finally, TF had greater relative percentage of 2X fibers than LN ($P < 0.05$), with GC not differing from either of them ($P > 0.10$). In study 1, there was a positive correlation between fiber type I and initial juiciness ($r = 0.37$; $P < 0.05$), sustained juiciness ($r = 0.39$; $P < 0.05$), and lipid flavor ($r = 0.41$; $P < 0.05$). Conversely, there was a negative correlation between fiber type 2A and initial juiciness ($r = -0.40$; $P < 0.05$), sustained juiciness ($r = -0.42$; $P < 0.05$), and lipid flavor ($r = -0.45$; $P < 0.01$). In study 2, a negative correlation was seen between type 2X fibers and myofibril tenderness ($r = -0.52$; $P < 0.05$), overall tenderness ($r = -0.46$; $P < 0.05$), and Warner-Bratzler shear force ($r = -0.46$; $P < 0.05$).

Conclusion: Like any antibody-based method, we recognize that the reported method is not perfect with concerns of hybrid fibers and minor cross-reactivity. However, our reported data are comparable to the muscle fiber typing results and correlations from many previous studies in beef. Given its efficacy and the high efficiency, muscle fiber typing via immunoblotting may prove to be a viable alternative.

Funding Source: Beef Checkoff.

Keywords: myosin heavy chain, type 1, type 2A, type 2X, western blot

## 154 METABOLOMICS DIFFER BY TEMPERAMENT IN BRAHMAN STEERS AND MAY BE RELATED TO PRODUCT QUALITY

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Objectives: Beef products are priced based primarily on quality. Quality of meat postmortem is affected by many live animal production traits, including animal temperament. The ability to predict meat quality by measuring factors in the live animal would greatly enhance our ability to manage them during the finishing phase. Our objective was to determine whether animal temperament impacted serum concentration of metabolites important to carcass traits.

Materials and Methods: At 14 mo of age, 7 calm (mean temperament score = 2.12), 6 intermediate (mean temperament score = 2.77), and 7 temperamental (mean temperament score = 3.77) Brahman steers were assigned temperament scores at weaning by exit velocity and pen score (1 = walks slowly, can be approached slowly, not excited by humans; 2 = runs along fences, stands in corner if humans stay away; 3 = runs along fences, head up and will run if humans come closer, stops before hitting gates and fences, avoids humans; 4 = runs, stays in back of the group, head high and very aware of humans, may run into fences and gates; 5 = excited, runs into fences, runs over anything in its path). Temperament score is calculated as (pen score + exit velocity) divided by 2. After 120 d in the feedlot, blood samples were obtained by jugular venipuncture. Harvested serum was promptly frozen and stored at −80°C until extracted with methanol and analyzed by high-performance liquid chromatography–quadrupole time-of-flight to identify and quantify the metabolic compounds present. Initial survey found 8,267 compounds that were then subjected to a filter that included at least 50% presence in at least one treatment, ANOVA ($P < 0.10$), and at least a 20-fold change between at least 2 means. The 73 resulting significant compounds were subjected to Tukey's HSD mean separation.

Results: Calm steers had 6 upregulated and 17 downregulated metabolites compared with intermediate steers and 13 upregulated and 39 downregulated metabolites compared with temperamental steers ($P < 0.05$). Intermediate steers had 19 upregulated and 40 downregulated metabolites compared with temperamental steers ($P < 0.05$). In a three-dimensional principal components analysis, the x-axis component accounted for 50.64%, the y-axis component 30.98%, and the z-axis component 18.38% of the variation in the model. Additionally, Pearson correlation coefficients indicate that some identified metabolites (from the METLIN metabolite library) like 1,2-dioctanoyl-sn-glycerol, which is involved in regulation of muscle calcium, had a moderately high negative ($r = -0.63$; $P = 0.003$) relationship with *longissimus* muscle marbling score. Conversely, marbling had moderate, positive correlations ($r = 0.56$ and 0.50, respectively; $P <$ 0.025) with geranyl acetoacetate (which helps synthesize

cholesterol) and 3-hydroxy-tetradecanedioc acid (which is involved in beta-oxidation of lipids in the mitochondria; a buildup of this long-chain fatty acid may indicate a malfunction in the mitochondrial trifunctional protein).

Conclusion: These results suggest that metabolites in Brahman steer serum were affected by animal temperament score and that some of the identified metabolites could potentially be indicators of the quality of beef carcasses prior to harvest.

Funding Source: Funding Grant number: USDA AFRI 2021-67015-33392.

Keywords: beef, carcass characteristics, marbling, metabolomics, temperament

## 155 PHOSPHOLIPASE A2 CONTRIBUTES TO FREE FATTY ACID GENERATION AND LIPID OXIDATION IN A BEEF LIPOSOME MODEL SYSTEM

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Objectives: Phospholipase-$A_2$ (PLA2) is a ubiquitous enzyme that cleaves a fatty acid tail at the sn-2 position from a phospholipid (PL). In the prior stage of this research reported in last year's RMC (Chun et al., 2021), it was found that the addition of PLA2 in a beef liposome model system altered the PL composition and influenced lipid oxidation. This could be due, in part, to the free fatty acids (FFA) that were released during PL hydrolysis by PLA2. The model system also showed a potential antioxidant (AOx) effect with the addition of PLA2 antibody (aPLA2). Therefore, the objective of this study was to elucidate the mechanisms of PL hydrolysis by PLA2 and determine whether there is an AOx effect from a combination of PLA2 and aPLA2.

Materials and Methods: The model system and the respective treatment were discussed in last year's RMC abstracts (Chun et al., 2021). Briefly, the 6 treatments are as follows: 1) PL (10 mg/mL of PL); 2) aPLA10 (PL + 10 μg/mL of aPLA2); 3) aPLA20 (PL + 20 μg/mL of aPLA2); 4) PLA2 (PL + 4 μg/mL of PLA2); 5) PLA2 + aPLA10 (PL + PLA2 + 10 μg/mL of aPLA2); and 6) PLA2 + aPLA20 (PL + PLA2 + 20 μg/mL of aPLA2). The aPLA2 was extracted from egg powder from hens immunized against porcine pancreatic PLA2. Enzyme-linked immunoassay was performed to show the presence and reactivity of extracted aPLA2. The FFA were quantified as fatty acyl anions using electrospray ionization mass spectrometry in negative mode. To measure the AOx capacity of the treatments at 0, 1, 4, and 7 d of display, the lipophilic portion was extracted with hexane and the hydrophilic portion with 20% ethanol, and the oxygen radical absorbance (ORAC) was measured on both fractions.

Results: The FFA profile showed that treatments containing PLA2, regardless of the addition of aPLA2, had greater amounts of 16:1, 18:1, 18:2, 20:4, and 20:5 ($P < 0.01$), but no treatment difference were found for any of the saturated FFA such as 18:0 and 16:0 ($P > 0.05$). There was also a display × treatment interaction for hydrophobic and lipophilic ORAC ($P < 0.01$). In hydrophilic ORAC, samples with PLA2 had higher AOx capacity than samples without PLA2 ($P < 0.01$). Samples without PLA2 increased in AOx capacity after 4 d of retail display ($P < 0.01$), whereas AOx capacity of samples with PLA2 stayed stable throughout the display period ($P > 0.05$). In lipophilic ORAC, samples with PLA2 showed higher AOx capacity than treatments with no PLA2 at 0 d ($P < 0.01$), but the enhanced AOx capacity from the PLA2 samples stabilized after 1 d and stayed stable through the rest of the 7-d display period ($P > 0.05$). The aPLA20 samples showed slightly higher AOx capacity than PL samples at 0 d ($P < 0.01$), but this enhancement also quickly mitigated after 1 d of display ($P > 0.05$).

Conclusion: We confirmed that PLA2 will liberate FFA during PL hydrolysis in a beef liposome system, particularly 18:2 and 20:4. Past research showed that these two fatty acids frequently appeared at the sn-2 position of PL, making them prime targets of PLA2 hydrolysis and susceptible to lipid oxidation. Although the addition of PLA2 will result in extensive PL hydrolysis, PLA2 also increased AOx capacity in the beef liposome system. Finally, although aPLA2 binding to PLA2 was demonstrated through enzyme-linked immunoassay, aPLA2 did not inhibit PLA2 activity in the model system. Further research is needed to determine how to inhibit PL hydrolysis but preserve PLA2 AOx capacity to better extend beef shelf life.

Keywords: anti-phospholipase $A_2$, free fatty acids, oxygen radical absorbance assay, phospholipid

## 156 EXTENDED AGING MODIFIED INTRAMUSCULAR CONNECTIVE TISSUE STRUCTURE IN BEEF AND IT MAY IMPACT CONNECTIVE TISSUE TEXTURE

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Objectives: Intramuscular connective tissue (IMCT) is the main contributor to background toughness in meat. At last year's RMC, we reported that extended aging softened

IMCT texture and demonstrated native collagenase activity in beef throughout 4 aging periods (Koulicoff et al., 2021). We speculated that IMCT components, such as collagen and proteoglycans, were weakened by native collagenase during postmortem aging but could not provide concrete proof. Hence, this study aimed to detect structural modifications of IMCT during extended aging period.

Materials and Methods: *Longissimus lumborum* (LL), *Gluteus medius* (GM), and *gastrocnemius* (GN) muscles from both sides were acquired from 10 USDA Choice beef carcasses. Each muscle was fabricated into steaks and aged at 2°C for: 3, 21, 42, and 63 d. Immunoblotting was conducted using 5 matrix metalloproteinase (MMP) antibodies to identify the active collagenase in the 3 beef muscles. Native form of collagen was also extracted from each sample using pepsin in acetic acid, and the collagen structure was revealed by gel electrophoresis. Aggrecan is a large aggregating proteoglycan that is a known substrate of MMP, and its degradation was quantified by immunoblotting using anti-aggrecan. Finally, peak transitional temperature of perimysium was measured to confirm IMCT integrity.

Results: The native collagenase in beef was identified as MMP-9 based on the immunoblotting detection. An aggrecan fragment was detected at 75 kDa and showed a muscle × aging interaction ($P < 0.01$). Both LL and GN showed a decrease in the aggrecan fragment intensity from 3 to 42 d of postmortem aging ($P < 0.05$), but GM did not show any alteration in the aggrecan fragment intensity among the aging periods ($P > 0.10$). The GN and LL had more aggrecan fragments than GM for both 3 and 21 d aging periods ($P < 0.01$). However, all 3 muscles had similar amounts of aggrecan fragments after 21 d of aging ($P > 0.10$). Purified native collagen from each sample was separated into 4 major bands at 300, 250, 139, and 129 kDa and were identified as γ, β, α1, and α2 chains, respectively. The γ and β are polymeric collagen chains with inter- and intramolecular cross-linkages, whereas both α1 and α2 are monomeric collagen chain with no cross-linkage. The relative intensity of γ chain decreased from 21 d to 63 d postmortem aging ($P < 0.01$). No difference was found for β chain relative intensity in any of the aging periods ($P > 0.10$). The relative intensity of α1 chain increased from 3 d to 42 d of postmortem aging ($P < 0.05$). The relative intensity of the α2 band for GN tended to increase from 3 to 21 d ($P < 0.10$), but no alteration was noted beyond 21 d of postmortem aging ($P > 0.10$). Finally, the transition temperature from IMCT of beef decreased from 3 to 42 d of mortem aging ($P < 0.01$) and remained stable beyond 42 d of postmortem aging ($P > 0.10$).

Conclusion: This study confirmed collagen and proteoglycan structural modifications and MMP-9 activity during the postmortem aging periods. These findings could be used to explain the decrease in the connective tissue amount detected by trained panelist and connective tissue shear force after extended postmortem aging as reported in our previous study. However, more research is needed to fully establish the mechanism of collagen and proteoglycan degradation by MMP-9 in the meat tenderization process.

Keywords: aggrecan, collagen, collagenase, matrix metalloproteinase

## *157 INVESTIGATION OF THE HEME CREVICE OF BOVINE AND TROUT IV METHEMOGLOBIN WITH PLASMA INDUCED MODIFICATION OF BIOMOLECULES (PLIMB)*

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Objectives: The study objective was to determine differences in solvent access to the heme crevice of bovine and trout IV methemoglobin. Trout IV methemoglobin has 27-fold lower heme affinity at pH 6.3 compared with bovine methemoglobin. Crystal structures suggest that more space is available for solvent access in trout IV compared with bovine hemoglobin, which could lead to protonation of the proximal histidine and subsequent loss of heme. Plasma Induced Modification of Biomolecules (PLIMB) was used to probe solvent access by generating hydroxyl radicals to modify amino acid side chains in a solvent accessible manner.

Materials and Methods: A 10 kilohertz signal of 10 volts was generated and amplified to 10 kV, which was then discharged from a steel needle 1 mm above protein in buffer. One hundred μL of hemoglobin (20 μM, heme basis) in sodium phosphate buffer (50 mM, pH 6.5) was used per exposure. Experimental replicates (3) of both the protein type (2) and time of exposure (3) were used for a combined total of 18 samples. Statistically, ANOVA ($n = 18$) was used to determine effect of PLIMB (dose dependency) and differences between species. Protein secondary structure was measure by scanning from 300 to 185 nm with a Circular Dichroism Spectrometer (Aviv Model 420). Molar ellipticity at 222 nm was used to statistically compare samples for loss of secondary structure. After a trypsin/LysC digest, samples were eluted with a C18 OMIX tip. Samples were injected into a hybrid linear ion trap-orbitrap mass spectrometer (LTQ-Orbitrap Elite) after chromatographic separation with Pepmap C18, 15 cm reversed phase column and ionized with an EASY-Spray Ion Source. Samples were analyzed in data-dependent tandem mass spectrometry mode and with Protein Metrics Byos software. Plasma-induced modifications of side chains included I) mono-oxidation as + 15.99 Da, II) di-oxidation as + 31.99 Da, III) His to Asp as −22.032 Da, IV) His to Asn as −23.016 Da, and V) Nitration as + 44.98 Da.

Results: There are 17 residues within 4 angstroms of the protoporphyrin IX ring in hemoglobin. Of those, 9 residues

in bovine α and 3 residues in bovine β had validated modifications, but only 1 residue (C7; 7th residue of the C chain) was dose dependent ($P < 0.005$). In trout IV methemoglobin, 4 residues were validated in trout IV α whereas 3 residues were validated in trout IV β, but only 2 residues were dose dependent (C7 [$P < 0.009$] and CE3 in the α chain [$P < 0.09$]). Based on crystal structures (Aranda et al., 2009), bovine CE3 is less static and therefore more difficult to modify than trout IV CE3, leading to less modification of bovine CE3 ($P < 0.002$). This in turn could allow more solvent into the heme crevice, explaining more solvent access in bovine C7 compared with trout IV C7 ($P < 0.008$).

Conclusion: This work demonstrates the ability of PLIMB to be used as a probe to understand the heme crevice in relation to lipid oxidation mediated by released heme. Trout IV methemoglobin does not have more modification in the proximal heme crevice residues compared with bovine methemoglobin, suggesting that the protonation of the proximal histidine is not the main reason for observed differences in bovine and trout IV methemoglobin heme affinity. Functionality of amino acid residues other than the proximal histidine might play a larger role than originally thought in the heme affinity of bovine and trout IV hemoglobin.

Funding Source: Improving Food Quality Foundational Program Award No. 2019-67017-29179 of the National Institute of Food and Agriculture.

Keywords: heme, hemoglobin, oxidation, protein footprinting

## 158 SUPPLEMENTATION OF SUCROSE AND (OR) BEEF DURING SOW GESTATION DID NOT AFFECT INSULIN RECEPTOR DENSITY ON THE SURFACE OR THE CROSS-SECTION OF FETAL MYOFIBERS

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Objectives: Using pregnant sows as a biomedical model of pregnant women, the objective of this study was to determine the effects of sucrose and/or beef supplements in a control maternal diet on the insulin receptor density of fetal muscle.

Materials and Methods: Twenty-one pregnant sows (Landrace × Yorkshire, starting body weight = 222 ± 35 kg) were randomly assigned to 1 of 4 isocaloric supplement treatments: control (CON) 126 g corn-soybean meal-based diet (CSM), 110 g cooked ground beef (BEEF), 85.5 g sucrose (SUG), or the combination of 54.8 g BEEF and 42.7 g SUG (BS). Dietary supplements were offered 3 times per day from day 40 to 110 of gestation. Sows were euthanized on day 111 of gestation. *Longissimus dorsi* and *semimembranosus* (SM) samples were collected from 1 median weight male and female fetus of each sow. Samples were immunofluorescent stained to target insulin receptors in skeletal muscle and analyzed through fluorescent microscopy to determine the insulin receptor density, expressed as the relative intensity (RI) or relative expression of the fluorescent dye on a specific area of tissue. Data were analyzed using the MIXED procedure of SAS, with sow diet, fetal muscle, and fetal gender as fixed effects and replicates as a random effect and with individual sow as the experimental unit. Correlations were made for the RI of the insulin receptor quantified on the myofiber surface versus the myofiber cross-section. Differences were considered statistically significant at $P \leq 0.05$.

Results: Interactions between treatments were not significant. The maternal diets did not affect the RI of the insulin receptors on the surface or the cross-section of the myofibers ($P = 0.7232$ and $P = 0.7611$, respectively), but numerical differences were found where SUG had the lowest values for *longissimus dorsi* and CON for SM. No differences were observed between gender for fetal myofibrillar RI ($P = 0.5545$ for surface and $P = 0.4807$ for the cross-section). In contrast, the muscle type influenced the RI of the insulin receptor on the

**Table 1.** Treatment main effects for insulin receptor relative intensity of immunofluorescent staining of fetal myofibrillar surface or cross-sectional slices of longissimus dorsi and semimembranosus muscle obtained at 111 d of gestation

| | | Treatment* | | | | |
|---|---|---|---|---|---|---|
| Tissue morphological presentation | Fetal Muscle+ | CON | B + S | SUGAR | BEEF | P value[1] |
| **Myofiber surface** | LD | 19.40 ± 1.99 | 22.06 ± 1.99 | 19.03 ± 1.99 | 22.47 ± 1.82 | 0.4936 |
| | SM | 21.92 ± 3.10 | 23.67 ± 3.10 | 23.56 ± 3.10 | 24.88 ± 2.83 | 0.9185 |
| **Myofiber cross-section** | LD | 15.49 ± 1.92 | 15.23 ± 1.92 | 14.08 ± 1.92 | 17.73 ± 1.76 | 0.5631 |
| | SM | 15.54 ± 2.31 | 16.60 ± 2.31 | 16.83 ± 2.31 | 17.39 ± 2.11 | 0.9470 |

*Control (CON) = 126g corn-soybean meal-based diet (CSM); BEEF = 110g cooked ground beef; SUG = 85.5g sucrose; BS = 54.8g BEEF + 42.7g SUG.

+LD = longissimus dorsi. SM = semimembranosus.

[1]Values are significant at $P \leq 0.05$.

surface of the myofiber ($P = 0.0175$) where SM had the highest density of insulin receptor.

Conclusion: Results from this study suggest that the amount of beef or sucrose supplementation to a standard maternal sow diet had minimal effects on the insulin receptor concentration of fetal muscle.

Keywords: ground beef, insulin receptor, maternal diet, sucrose, swine

## 159 SOLVENT STABILIZERS PERSIST AFTER LIPID FRACTIONATION INCURRING UNINTENDED ANTIOXIDANT ACTIVITY IN MUSCLE SYSTEMS

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Objectives: Lipid fractionation via solid phase extraction, using silica-backed amino propyl resin, proves to be an effective means of separating lipids into their constituent groups (neutral lipids, free fatty acids [FFA], polar lipids) from crude lipid extracts. In the present study, FFA extracted using 2% acetic acid in diethyl ether (DEE) (v/v) were of particular interest. This work aimed to determine the antioxidant capacity of trace butylated hydroxytoluene (BHT), derived from stabilized DEE, that persists in the extracted FFA. It was hypothesized that, when extracting FFA using DEE stabilized with BHT, followed by application into muscle systems, antioxidant activity would be observed. In contrast, when extracting FFA using un-stabilized DEE, no antioxidant activity would be observed.

Materials and Methods: Total lipids were extracted from turkey (*Meleagris gallopavo*) epidermis. The FFA were separated from the total lipids via solid phase extraction, using 2% acetic acid in DEE (v/v) as the extraction solvent. Two types of DEE were evaluated: 1) commercial DEE (stabilized with 6 ppm BHT) and 2) commercial DEE (un-stabilized). FFA fractions, derived from extraction solvents using DEE 1 and 2, were subject to gas chromatography-mass spectrometry (GC-MS) for compositional analysis, following methylation. GC-MS was performed using an Agilent 7890A GC coupled to Agilent 7975C mass detector, with ion monitoring in SCAN mode targeting m/z 40–400. GC-MS data were analyzed using OpenChrom (version 1.4.0) equipped with MassBank (NIST) database. Additionally, FFA fractions, applied at 100 ppm, were assayed for the antioxidant capacity as measured by thiobarbituric reactive substances and $a^*$ values, in washed turkey breast muscle (WTBM) and minced turkey thigh muscle (TTM), respectively. Methemoglobin (40 μmol/kg WTBM) was added as a pro-oxidant in the washed muscle system. The final pH of the WTBM and TTM muscle were 6.7 and 6.3, respectively. Ethanol was used as a lipid carrier at 2% (w/w), for both the washed and minced muscle systems. Samples were stored on ice (2°C), in the dark, for up to 6 d. Statistics were analyzed via two-way ANOVA and Tukey's pairwise comparison in JMP Pro (version 15.0.0).

Results: Based on gravimetric analysis of the extracted FFA fraction, and the known BHT concentration in DEE 1, 100 ppm of the added FFA fraction equates to an application of ~15 ppm BHT, on a tissue basis. GC-MS analysis indicated the presence of BHT when DEE 1 was used in the extraction solution. No differences in fatty acid composition were observed when FFA extracted with DEE 1 was compared with that extracted with DEE 2. A significant ($P < 0.05$) depression in thiobarbituric reactive substance value was observed in the WTBM system, when FFA extracted using DEE 1 was added but not FFA extracted using DEE 2. When FFA extracted using DEE 1 was added to TTM, a significantly ($P < 0.05$) higher $a^*$ value was observed after 6 d of storage compared with FFA extracted using DEE 2.

Conclusion: BHT stabilizer in DEE has the potential to be retained within the aminopropyl resin during lipid fractionation or be eluted with and thereby contaminate the FFA fraction. Our findings indicate that at least some of the BHT stabilizer elutes with the FFA fraction incurring unintended antioxidant functionality of the obtained lipid fraction.

Keywords: butylated hydroxytoluene, gas chromatography-mass spectrometry, lipid oxidation

## 160 DISTINCT PROTEOMIC AND METABOLOMIC PROFILES ARE ASSOCIATED WITH THE INSTRUMENTAL TEXTURE OF AGED PORK LOIN

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Objectives: There is significant interest in defining biochemical features of pork that contribute to variation in fresh pork tenderness. Recognition of proteomic and metabolomic phenotypes in fresh pork loin associated with tenderness will inform decisions to pursue selection protocols and develop

biomarkers for pork tenderness. This study aimed to define proteomic and metabolomic features of fresh pork loin chops that demonstrate varying instrumental texture phenotypes.

Materials and Methods: Fresh pork loins ($N = 120$) were collected from a commercial harvest facility and aged 12 to 14 d postmortem. Loin chops (2.54 cm) were trimmed to contain only the *longissimus* muscle. Color, marbling, pH, cook loss, star probe, and sensory quality were determined. Star probe values were used to segregate loins into 4 categories (A: 3.4–4.5 kg; B: 4.7–5 kg; C: 5.2–5.6 kg; and D: 5.7–7.4 kg), chops from 25 loins per category were selected for tandem mass tag analysis. Proteins soluble in a low ionic strength buffer (50 mM Tris-HCl, pH 8.5, and 1 mM EDTA) were extracted, digested with trypsin, and labeled with 11-plex isobaric tandem mass tag labels. Peptides were introduced to the Q-Exactive Hybrid Quadrupole-Orbitrap Mass Spectrometer and identified and quantified with Proteome Discoverer. Data were normalized to the total ion count from each run, Log2 transformed, and median normalized. Only proteins identified in at least half the samples containing at least 2 unique peptides were included in the analysis. Non-targeted metabolome analysis was conducted on extracts (80% methanol) of each sample. Separation was conducted with a TG-5MS column (Thermo Scientific, 30 m × 0.25 mm × 0.25 mm). Masses between 50 and 620 m/z were scanned at 4 scans/s after electron impact ionization operating at 70 eV. All data were analyzed in R 4.1.1 using the limma package with a false discovery rate of 0.05.

Results: A total of 307 proteins were included in the analysis. A differential abundance of 76 proteins/peptides were identified ($P < 0.05$) between Categories A and D. Category A chops generally had better sensory traits than Category D. Proteins/peptides that were in greater abundance in Category A included structural proteins (desmin, filamin, alpha-actinin, titin), sarcoplasmic reticulum proteins (calsequestrin, calcium transporting ATPase), chaperone proteins (Heat shock protein 27, Alpha/B crystallin), and metabolic enzymes (AMP deaminase, Succinate CoA ligase, isocitrate dehydrogenase). Protein/peptides greater in abundance in Category D included metabolic enzymes (phosphoglucomutase-1, fructose-bisphosphate aldolase, lactate dehydrogenase, phosphoglycerate mutase, and adenylate kinase) and some membrane-associated proteins (junctophilin, annexin). Forty-six metabolites were included in the analysis. Nine metabolites, including glucose 6-phosphate, fructose, galactose, and glucose, were more abundant in Category D. Thirteen metabolites, including amino acids and glutamic acids, were more abundant in Category A.

Conclusion: Identification of peptides from structural proteins in the soluble fraction of Category A is consistent with greater proteolysis in products with lower star probe values. The observation of a greater abundance of glycolytic enzymes and sugars in Category D supports the hypothesis that increased capacity for glycolysis can be detrimental to pathways that improve tenderness in pork.

Funding Source: Funding, wholly or in part, was provided by the Iowa Pork Producers Association.

Keywords: metabolomics, pork quality, proteomics

## 161 RELATIONSHIP OF THE SARCOPLASMIC PHOSPHOPROTEOME TO VARIATIONS IN TENDERNESS FROM STEERS FED SUPRANUTRITIONAL ZINC AND RACTOPAMINE HYDROCHLORIDE

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Objectives: The hypothesis was that differences in the early postmortem (PM) phosphoproteome of *longissimus thoracis* (LT) muscle from beef cattle supplemented with supranutritional zinc (Zn) and ractopamine hydrochloride (RAC) influence pH values and early PM tenderness.

Materials and Methods: Steers were assigned to diets based on growth potential and initial body weight: non–Zn-supplemented control (CON-NO; 36 mg Zn/kg dry matter; $n = 5$), supranutritional Zn supplementation (SUPZN-NO; CON diet + 60 ppm Zn from $ZnSO_4$ + 60 ppm Zn from Zn-amino acid complex; $n = 5$), CON + RAC supplementation (CON-RAC; 300 mg RAC-steer$^{-1}$ d$^{-1}$; $n = 5$), and SUPZN + RAC supplementation (SUPZN-RAC; $n = 5$). Zn treatments were fed for the 89-d trial. RAC was fed for the final 28 d before harvest. On 5 different harvest dates, 1 steer per treatment was harvested ($n = 4$/d). LT pH values were taken (1, 3, 6, and 24 h PM). LT muscle samples were taken at 1 h PM and frozen. Steaks for Warner-Bratzler shear force (WBSF) were collected, and WBSF was determined on cooked (68°C) steaks (2.54 cm; 1, 3, 7, or 14 d PM). WBSF and pH data were analyzed as a 2 × 2 factorial using the mixed procedure of SAS version 9.4 (fixed effects = Zn, RAC, and the interaction; block = harvest date). Significance was $P \leq 0.05$, and trends were $0.05 < P \leq 0.10$. Sarcoplasmic protein extracts (1 h PM) were used for two-dimensional electrophoresis. Two-dimensional electrophoresis was completed, and gels were fixed, stained with phosphoprotein stain and total protein stain, and imaged according to the manufacturer's recommendations. Phosphoproteome gels were analyzed using Melanie software version 9.2.5, and *t* tests were conducted on individual treatment comparisons. Significant ($P < 0.10$; fold change > 1.25) spots were excised from gels using a pooled reference sample stained with filtered Colloidal Coomassie Blue Stain. Spots were digested in trypsin, and peptide fragments were

**Table 1.** Phosphoproteome comparison at 1-hour postmortem of muscle from cattle supplemented supranutritional zinc (Zn) and ractopamine hydrochloride (RH)

| | | | | Fold Change | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Protein | Accession Number | Coverage, % | Unique Peptides | CON-RAC\ CON-NO | SUPZN-NO\ CON-NO | SUPZN-RAC\ CON-NO | SUPZN-NO\ CON-RAC | SUPZN-RAC\ CON-RAC | SUPZN-RAC\ SUPZN-NO | Location |
| **Energy Production** | | | | | | | | | | |
| Malate Dehydrogenase | Q3T145 | 45 | 15 | **1.58** | 0.94 | 0.91 | **0.59** | **0.57** | 0.97 | Cytoplasm |
| ATP synthase subunit beta | A0A4W2EL77 | 48 | 19 | **1.58** | 1.17 | 0.88 | **0.74** | **0.55** | **0.75** | Mitochondria, membranes |
| Phosphoglucomutase-1 | A0A3Q1LRD1 | 62 | 1 | **1.39** | **1.46** | **0.78** | 1.05 | **0.56** | **0.54** | Sarcoplasm |
| Phosphoglucomutase-1 | A0A4W2F139 | 64 | 1 | **1.41** | **1.78** | 0.94 | **1.27** | **0.67** | **0.53** | Sarcoplasm |
| Phosphoglucomutase-1 | A0A4W2F139 | 27 | 12 | **1.68** | **1.28** | 0.86 | **0.76** | **0.51** | **0.67** | Sarcoplasm |
| **Apoptosis** | | | | | | | | | | |
| Heat shock 70 kDa protein 1A | K9ZRL4 | 45 | 1 | **0.73** | 1.07 | **0.66** | **1.46** | 0.90 | **0.62** | Nucleoplasm, vesicles, cytosol |
| Heat shock 70 kDa protein 1A | K9ZRL4 | 42 | 14 | 0.81 | 1.14 | **0.67** | **1.40** | 0.82 | **0.59** | Nucleoplasm, vesicles, cytosol |
| Heat shock 70 kDa protein 4 | A0A4W2FG09 | 34 | 23 | 0.17 | **0.71** | **1.43** | **0.60** | 1.21 | **2.02** | Sarcoplasm |

CON = no supplemental Zn (analyzed 36 mg Zn/kg dry matter [DM]): SUPZN = COX + 60 mg Zn/kg DM from ZnSO4 + 60 mg Zn/kg DM from Zn-amino acid complex (Availa-Zn; Zinpro Corporation, Eden Prairie, MN). Fed for the entire 89 d trial.

NO = no supplemental ractopamine hydrochloride (RH): RAC = 300 mg RH per head per d (Actogain45; Zoetis, Parsippany, NJ) starting 28 d before harvest.

Modifications of phosphorylation (Ser, Thr) were analyzed for each protein.

CON-NO= No Zn or RH supplementation. CON-RAC= No Zn supplementation, only RH supplantation. SUPZN-NO= Zn supplementation, no RH supplementation. SUPZN-RAC= Zn and RH supplementation.

Bolded fold change value comparisons are significant ($P$-value< 0.10).

compared to known databases against *Bos Taurus* for protein identification.

Results: At 6 h PM, Zn supplementation trended to lower ($P = 0.0638$) LT pH than non–Zn-supplemented steers. LT from RAC-fed steers had a greater pH ($P = 0.04$) at 6 h PM than non–RAC-supplemented steers. RAC supplementation resulted in greater ($P < 0.01$) WBSF values than muscle from non–RAC-supplemented steers. Zn supplementation trended for a lower ($P = 0.0585$) WBSF at 1 d PM than steaks from non–Zn-supplemented steers. CON-RAC had a greater abundance of identified phosphorylated isoforms of malate dehydrogenase, ATP synthase subunit beta, and phosphoglucomutase-1 (PGM1) than all other treatments. SUPZN-NO had a greater abundance of phosphorylated isoforms of heat shock 70-kDa protein 1A (HSPA1A) and a lesser abundance of a phosphorylated isoform of heat shock 70-kDa protein 4 (HSPA4) than CON-RAC or SUPZN-RAC. SUPZN-NO had a greater abundance of a phosphorylated isoform of PGM1 (most acidic spot in the train of PGM1 spots) than all other treatments.

Conclusion: Differences in abundances of phosphorylated isoforms of oxidative and glycolytic enzymes were linked to nutritional treatments that resulted in variations in pH decline. Greater abundances of phosphorylated isoforms of HSPA1A and a lesser abundance of HSPA4 could be related to greater apoptosis in SUPZN-NO, which could explain lesser WBSF values in the SUPZN-NO treatment. Features of the phosphoproteome of muscle can be used to help explain differences in early PM metabolism and resulting meat quality.

Funding Source: This work is supported by the Agriculture and Food Research Initiative (AFRI) grant no. 2018-67015-27546/project accession no. 1015001 from the USDA National Institute of Food and Agriculture.

Keywords: beef, pH decline, phosphoproteome

## 162 CHARACTERIZING THE PROTEOME OF AGED PORK LOINS CLASSIFIED BY PURGE LOSS

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Objectives: The consistent production of high-quality pork remains a challenge as fresh pork products can vary in their water-holding capacity. Understanding the diverse factors that influence fresh pork water-holding capacity is imperative. Therefore, the objective of this study was to use tandem mass tag (TMT) analysis to evaluate the proteome of aged pork loins classified by purge loss. It was hypothesized that pork chops with low purge loss would have a greater abundance of structural proteins in soluble fraction, contributing to their ability to retain a greater amount of water.

Materials and Methods: Fresh pork loins ($n = 100$) were aged for 12 to 14 d postmortem. Chops (2.54 cm) were fabricated and evaluated for purge, ultimate pH, Hunter L value, visual color and marbling, cook loss, star probe, and sensory. The samples were selected for TMT analysis based on chop purge loss in 1 d of retail storage. Chops were classified into Low ($n = 27$, average purge = 0.36%), Intermediate ($n = 27$, average purge = 0.72%), or High ($n = 27$, average purge = 1.16%) chop purge groups. Proteins soluble in a low ionic strength buffer (50 mM Tris-HCl, pH 8.5, and 1 mM EDTA) were extracted, digested with trypsin, and labeled with 11-plex isobaric TMT analysis. Peptides were introduced to the Q-Exactive Hybrid Quadrupole-Orbitrap Mass Spectrometer and identified and quantified with Proteome Discoverer. Data were normalized to the total ion count from each run, Log2 transformed, and median normalized. Only proteins identified in at least half of the samples containing at least 2 unique peptides were included in the analysis. Data were analyzed in R 4.1.1 using the limma package with a false discovery rate of 0.05.

**Table 1.** A summary of proteins different between the Low and High chop purge classifications.

| Protein Description | Log2 Fold Change[1] | Adjusted P-Value |
|---|---|---|
| *Structural* | | |
| Titin | 0.54 | 0.017 |
| Desmin | 0.52 | 0.015 |
| Filamin C | 0.34 | 0.007 |
| Obscurin | 0.25 | 0.013 |
| Dystrophin | −0.20 | 0.013 |
| *Contractile* | | |
| Troponin-C | 0.47 | 0.017 |
| Myosin Regulatory Light Chain 2 | 0.25 | 0.017 |
| *Calcium Regulating* | | |
| Calsequestrin-1 | 0.77 | 0.015 |
| Calcium Transport ATPase 1 | 0.50 | 0.015 |
| Calcium Transport ATPase 2 | 0.44 | 0.015 |

[1]Positive Log2 value indicates greater abundance in Low vs High. Negative Log2 value indicates lesser abundance in Low vs High.

Results: A total of 307 proteins were included in the analysis. No proteins were different between the Low and Intermediate ($P > 0.05$) or Intermediate and High ($P > 0.05$) classification comparisons. Between the Low and High classification comparisons, 46 proteins were differentially ($P < 0.05$) abundant. These proteins can be classified primarily as structural and contractile, metabolic, calcium regulating, or chaperone proteins based on their known function in skeletal muscle. Generally, the Low group had a greater abundance of proteins classified as structural and contractile, calcium regulating, and chaperone than the High group. A lesser abundance of glycolytic proteins was determined in the Low purge chops.

Conclusion: A moderate difference in chop purge between the Low and High classification results in proteome differences between these samples. Chops in the Low group had a greater abundance of myofibrillar, calcium regulating, chaperone proteins and less metabolic proteins in the low-ionic-strength fraction. Myofibrillar proteins are not soluble under low-ionic-strength conditions and thus are likely degradation products. This supports our hypothesis that pork chops with low purge have a greater abundance of structural proteins in the low-ionic-strength fraction. These results also confirm earlier observations of greater desmin degradation associated with less chop purge. Together, these and other proteins may serve as biomarkers of water-holding capacity in the soluble fraction of aged pork chops. Additional research early postmortem and over subsequent storage days would provide further evidence to better characterize the mechanisms and relationships between these proteins and pork water-holding capacity.

Funding Source: Funding, wholly or in part, was provided by the Iowa Pork Producers Association.

Keywords: pork, proteomics, water-holding capacity

## *163 EXPOSURE OF CALPAIN-2 TO DIFFERENT LIPID OXIDATION PRODUCTS AFFECTS ACTIVITY AND AUTOLYSIS*

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Objectives: Calpains are a family of calcium-dependent cysteine proteinases. The active site of calpains is susceptible to oxidation, which could decrease their proteolytic activity. The oxidation of lipids yields various oxidation products, including malondialdehyde (MDA), hexenal (HXL), and 4-hydroxynonenol (HNE). The susceptibility of calpain-2 to oxidation by MDA, HXL, and HNE is unknown. Therefore, the objective was to conduct *in vitro* incubations of pure calpain-2 with

MDA, HXL, and HNE to determine their impact on calpain-2 activity and autolysis. It was hypothesized that MDA, HXL, and HNE decrease the caseinolytic activity of calpain-2 and slow calpain-2 autolysis.

Materials and Methods: Calpain-2 was purified from porcine *semimembranosus* muscle collected 45 min postmortem using successive column chromatography. Prior to *in vitro* experiments, calpain-2 was dialyzed against 40 mM Tris-HCl (pH 7.4), 1 mM EDTA, and 0.1% 2-mercaptoethanol for 3 h at 4°C. Pure calpain-2 was incubated with 100, 500, or 1,000 μM of either MDA, HXL, or HNE, or equal volumes of $ddH_2O$ or ethanol (controls), for 24 h at 4°C. After incubation, the caseinolytic activity of calpain-2 was determined in triplicate and replicated six ($n = 6$) times. Calpain-2 activity was expressed as a percentage of the control. Calpain-2 autolysis was assessed by incubation with either 1,000 μM MDA, HXL, or HNE, or equal volumes of $ddH_2O$ or ethanol (controls) for 24 h at 4°C. Prior to the inclusion of $CaCl_2$, calpain-2 was removed and immediately added to protein denaturing buffer to serve as a no-calcium control. Each treatment was adjusted to 2 mM $CaCl_2$ and reacted on ice. Aliquots were removed at 5, 15, and 60 min and added to protein denaturing buffer. Two ($n = 2$) replicates of calpain-2 autolysis with each oxidant were conducted and visualized on 15% sodium dodecyl sulfate-polyacrylamide gel electrophoresis gels with Silver Staining. Calpain-2 activity was analyzed a one-way ANOVA using R 4.1.1 with fixed effect of concentration. Significance was determined by $P < 0.05$.

Results: Calpain-2 activity increased linearly with increasing MDA concentrations but was only greater than the control with 1,000 μM incubation ($P < 0.05$). Calpain-2 activity was less than the control after incubation with all concentrations of HXL ($P < 0.05$) and HNE ($P < 0.05$). Incubation with 1,000 μM of HXL and HNE reduced calpain-2 activity by approximately 40% and 50%, respectively. No differences in calpain-2 autolysis between MDA and control at 5, 15, or 60 min were observed. Calpain-2 autolysis was different between control and HXL, and control and HNE at 5, 15, and 60 min as evidenced by a slower disappearance of the 28 kDa small subunit and a slower appearance of the approximately 37 kDa autolysis product in the HXL and HNE treatments.

Conclusion: The interplay between lipid and protein oxidation is often not considered. These results demonstrated that MDA, HXL, and HNE have differing impacts on calpain-2 autolysis and activity *in vitro*. These data have shown that HXL and HNE have a negative impact on calpain-2 activity and autolysis. Interestingly, MDA does not impact calpain-2 activity and autolysis at concentrations physiologically relevant in skeletal muscle.

Keywords: calpain-2, lipid oxidation, protein oxidation

## *164 PECTORALIS MAJOR (BREAST MEAT) FATTY ACID METABOLISM IN BROILERS EXHIBITING WOODY BREAST MYOPATHY*

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Objectives: The wooden breast (WB) myopathy has a negative impact on broiler production efficiency and meat quality. Increased fat content was observed in WB muscles, indicating that dysregulation of fatty acids is related to triggering the WB condition. The objective of this study was to evaluate the expression of genes related to chicken fatty acid metabolism of WB muscle.

Materials and Methods: A total of 112 Ross × Ross 708 broilers were evenly distributed in a floor-pen chicken house with 14 birds per pen at the Poultry Research Farm at Mississippi State University (IACUC-16-542). The chicken husbandry followed the commercial recommendation for Ross 708 boilers. On day 41, breast muscle hardness in live birds was determined by palpation, and birds were grouped into normal and WB phenotypes. A total of 10 birds—5 exhibiting normal breast conditions and 5 exhibiting WB conditions—were selected for sampling. Birds were euthanized using $CO_2$, and 2 g of muscle was sampled within 15 min post slaughtering from the cranial portion of the breast muscle. Breast muscle RNA was extracted using a modified hot borate method. RNA concentration and quality were determined by Nanodrop and agarose electrophoresis. Reverse transcription was performed using SuperScript IV VILO Master Mix (Invitrogen). The first-strand complementary DNA was used on the real-time $RT^2$ Profiler PCR (polymerase chain reaction) Array (QIAGEN, PAGG-007Z) for a set of 84 chicken fatty acid metabolism-related genes and 5 housekeeping genes. Fold changes were calculated using the ΔΔCt method and were compared using the Student *t* test with the significance level set at $P \leq 0.05$.

Results: The $RT^2$ profiler PCR Array analysis revealed that 8 of the 84 examined genes were differentially expressed (≥ 1.5-fold change; $P \leq 0.05$) between normal breast and WB samples, including 3 upregulated and 5 downregulated genes in WB muscle compared with normal breast muscle. The upregulated genes in WB muscle—including acetyl-coenzyme A acetyltransferase 2, alcohol dehydrogenase 6, and glycerol kinase—are involved in multiple metabolism pathways (such as lipid biosynthesis, ethanol metabolism, and glycerol metabolism), whereas the 5 downregulated genes in WB muscle—containing acyl-coenzyme A dehydrogenase, acyl-coenzyme A synthetase medium-chain

family member 4, glycerol-3-phosphate dehydrogenase 2, 5'-AMP-activated protein kinase subunit beta-2, and 5'-AMP-activated protein kinase subunit gamma-3—mainly take place in fatty acid $\beta$ oxidation and the signal transduction pathway related to energy metabolism.

Conclusion: In conclusion, expression of genes in WB muscle involved the upregulation of lipid biosynthesis and the downregulation of fatty acid catabolism, indicating the dysregulation of lipid biosynthesis and catabolism. Identification of these potential gene biomarkers and signal pathways helps us better understand the biochemical mechanisms of WB formation.

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Keywords: fatty acids, lipid, PCR array, poultry, woody breast

## 165 IMPACT OF OXYGEN EXPOSURE ON THE LONGISSIMUS LUMBORUM, PSOAS MAJOR, AND SEMITENDINOSUS MUSCLES DURING RETAIL DISPLAY

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Objectives: Oxymyoglobin leads to a bright cherry-red pigment on the surface of meat, which is preferred by consumers. However, oxidation of ferrous myoglobin leads to formation of metmyoglobin and discoloration. Various factors such as pH, temperature, reducing capacity of meat, and oxygen partial pressure influence metmyoglobin formation. Myoglobin is prone to oxidation at a lower oxygen partial pressure. Hence, meat discoloration starts from the interior and spreads to the surface. In aerobic packaging, oxygen exposure to the cut surface in the retail package can increase oxidation; however, the connection between oxygen exposure to the retail surface and internal discoloration has not been clear. Limited research has evaluated the effect of oxygen exposure on the biochemical properties in retail compared with non–oxygen-exposed (NOE) interior of muscle. The objective of this study was to evaluate the effects of oxygen exposure on the biochemical attributes of *longissimus lumborum* (LL), *psoas major* (PM), and *semitendinosus* (ST) muscles.

Materials and Methods: USDA Low Choice short loins and eye of rounds (5 d postmortem) were purchased from a commercial packing facility and transported on ice to Oklahoma State University. Steaks were sliced (1.91 cm) from USDA Low Choice beef strip loins ($n = 7$), tenderloins ($n = 7$), and eye of rounds ($n = 7$). Steaks were packaged in pairs in polyvinyl chloride overwrap trays and randomly assigned to 3 or 6 d in retail display. One steak was used to analyze the muscles on day 0 for oxygen consumption (OC), metmyoglobin reducing ability (MRA), and lipid oxidation as the NOE surface. The surface exposed during retail display was oxygen exposed (OE), whereas interior muscle was denoted as NOE. To analyze the NOE surface, steaks were sliced parallel to the OE surface. Instrumental color was evaluated every day of retail display using a HunterLab MiniScan spectrophotometer. On days 3 and 6, OC and MRA were evaluated for the NOE and the OE surfaces. MRA was evaluated by metmyoglobin formation after submersion in nitrite solution, and OC was determined as oxymyoglobin formation in vacuum packaging after 30 min and 60 min. Lipid oxidation of both surfaces was evaluated on day 3 and 6. The GLIMMIX procedure of SAS was used to determine the least-squares means of 7 replicates. Least-squares means were separated using the PDIFF option with $P < 0.05$ considered significant.

Results: All 3 muscles decreased in $a^*$ values ($P < 0.05$), with retail display with the PM having the lowest ($P < 0.05$) $a^*$ followed by the LL and then the ST on day 6 of display. The NOE surface had greater ($P < 0.05$) MRA compared with the OE surface on days 3 and 6. Lipid oxidation was greater ($P < 0.05$) in the OE surface than the NOE surface on day 6. PM had greater ($P < 0.05$) lipid oxidation than the LL muscle. The OE surface of the PM had lower ($P < 0.05$) OC compared with the NOE surface on day 3 and 6 of retail display after 30 min. Both the NOE surface of the PM and ST muscles had greater ($P < 0.05$) OC after 60 min than the OE surface on days 3 and 6 of display.

Conclusion: The exposure to oxygen resulted in a decrease in MRA and OC aligning with a decline in retail color and increased lipid oxidation. In conclusion, oxygen exposure can negatively impact color stability while the nonexposed interior of muscle remains more biochemically active.

Keywords: meat color, metmyoglobin reducing ability, oxygen consumption

## 166 LIPID PEROXIDATION PRODUCTS INFLUENCE CALPAIN-1 ACTIVITY AND AUTOLYSIS IN VITRO

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Objectives: Meat tenderness significantly influences consumers' eating satisfaction and repurchase decisions. Calpains play a significant role in the postmortem tenderization of meat. Previous research has demonstrated that lipid peroxidation products can influence protein and enzyme functionality. However, their impact on calpains is not known. Therefore, the objective of the current study was to evaluate the effect of lipid peroxidation products, malondialdehyde (MDA), hexenal, and 4-hydroxynonenal (HNE), on calpain-1 activity and autolysis *in vitro*.

Materials and Methods: Purified porcine calpain-1 was dialyzed against a TEM buffer (40 mM Tris-HCl, pH 7.4, 1 mM ethylenediaminetetraacetic acid, and 0.1% β-mercaptoethanol) at 4°C. The calpain-1 was then incubated for 24 h at 4°C with 100, 500, or 1,000 μM of either MDA, hexenal, or HNE, or equal volumes of TEM (controls). After each incubation, calpain-1 activity was determined in triplicate using a caseinolytic assay (pH 7.4) at 25°C. Each experiment was repeated six times (n = 6), and the activity of each treatment was expressed as a percentage of the control samples. Progression of calpain-1 autolysis was evaluated in samples from control and the 1,000 μM treatments (MDA, hexenal, or HNE) using sodium dodecyl sulfate-polyacrylamide gel electrophoresis gels and was visualized by silver staining. A completely randomized design was used to analyze the effect of each lipid peroxidation product on calpain-1 relative activity. A one-way ANOVA was conducted, followed by a least-square means test to estimate the difference due to concentration ($P < 0.05$).

Results: The calpain-1 activity increased (compared with control) after incubation with 100 μM MDA ($P < 0.05$) but was not different than control after incubation with 500 μM and 1,000 μM MDA ($P > 0.05$). Hexenal and HNE incubations decreased calpain-1 activity at all 3 concentrations (100 μM, 500 μM, and 1,000 μM) as compared with control ($P < 0.05$). Specifically, calpain-1 activity decreased with the increase in the concentration of hexenal and HNE from 100 μM to 1,000 μM ($P < 0.05$). There was no visible difference in the progression of the autolysis of the 80 kDa subunit of calpain-1 between control and MDA treatments, but hexenal and HNE incubation slowed down the autolysis of the 80 kDa subunit. In addition, no visible differences were observed in the autolysis of the 28 kDa subunit between the control and the lipid peroxidation product treatments.

Conclusion: Calpain-1 activity was differentially influenced by lipid peroxidation products in a concentration-dependent manner *in vitro*. Hexenal and HNE slowed calpain-1 activity and autolysis, and MDA increased calpain-1 activity and autolysis at concentrations physiologically relevant in skeletal muscle. Further investigations are necessary to understand the mechanistic basis of these differences, including the adduction sites and their impacts on tenderness.

Keywords: cysteine protease, hexenal, 4-hydroxynonenal, malondialdehyde, proteolysis

## *167 EFFECT OF NICOTINAMIDE RIBOSIDE DIETARY SUPPLEMENTATION ON EARLY POSTMORTEM MITOCHONDRIA FUNCTIONALITY IN PORK LONGISSIMUS DORSI MUSCLE*

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Objectives: Nicotinamide riboside, a new pyridine-nucleoside form of vitamin B3, can be converted to nicotinamide adenine dinucleotide ($NAD^+$) in a two-step reaction catalyzed by nicotinamide riboside kinases 1/2 and nicotinic acid mononucleotide adenylyl-transferase. Increasing $NAD^+$ via nicotinamide riboside significantly protects mitochondrial function in humans. Mitochondria can influence animal production efficiency. Moreover, mitochondria functionality in postmortem muscle contributes to meat color and tenderness. A pilot study indicated that feeding nicotinamide riboside at the end of the finishing period could enhance pork loin chop redness and color stability during simulated retail display. However, the effect of nicotinamide riboside on pig skeletal muscle mitochondria has not been investigated. Therefore, the objective of this study was to examine the effect of nicotinamide riboside dietary supplementation on pork mitochondrial function during the early postmortem period.

Materials and Methods: Pork *longissimus dorsi* (LD) muscle were collected from the carcasses of nicotinamide riboside-fed (NR; 30 mg•hd-1•body weight-1 for 10 d; $n = 8$) and control (CON; diet without supplemental nicotinamide riboside; $n = 8$) pigs. Mitochondrial oxidative phosphorylation (OXPHOS) was evaluated during early postmortem period (45 min and 2 h postmortem) by a split-plot design. Data analysis was performed using R with the lme4 package as a mixed model, where treatment (CON or NR), postmortem time, and their interactions were the fixed effects, and random effect was individual pig. The differences between least-squares means ($P < 0.05$) were determined by Tukey's multiple comparison.

Results: A treatment × postmortem-time interaction ($P < 0.05$) was observed in the proton leak-associated respiration (supported by high NADH, but no ADP), maximal OXPHOS-linked respiration (supported by NADH, succinate, and NADH + succinate), maximal mitochondrial integral respiration capacity (supported by NADH + succinate + cytochrome c), and mitochondrial relative membrane damage. Despite mitochondrial respiration of LD declining ($P < 0.05$) with postmortem time (regardless of treatment), NR muscle had a slower ($P < 0.05$) loss in mitochondrial respiration and mitochondrial damage from 45 min to 24 h postmortem than CON muscle.

Conclusion: NR supplementation resulted in greater OXPHOS efficiency and fuel oxidation rates under conditions of low ATP demand in premortem pork LD muscle. Mitochondrial integral function declined slower in NR compared with CON muscle early postmortem, which could partly explain the higher color stability of NR LD during retail display.

Keywords: *longissimus dorsi*, mitochondrial function, nicotinamide adenine dinucleotide

## 168 TANDEM MASS TAG LABELING AND GAS CHROMATOGRAPHY-MASS SPECTROMETRY TO IDENTIFY SOLUBLE PROTEOME AND METABOLOME VARIATION AMONG PORK LONGISSIMUS WITH DIFFERING INSTRUMENTAL COLOR

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Objectives: Meat color significantly affects consumers' purchase decisions, and pale pork is typically less preferred by consumers. Previous studies have demonstrated that the proteome and metabolome profile of the muscles can influence meat color. Therefore, the objective of this study was to investigate the variation in soluble proteome and metabolome among pork *longissimus* muscles with differing instrumental color (lightness).

Materials and Methods: Fresh pork *longissimus* ($N = 100$) were collected from a commercial harvest facility and aged for 12 to 14 d postmortem before fabrication and quality evaluation. After tandem mass tag analysis for all muscle samples, a sample subset ($N = 86$) was selected and categorized into 3 groups according to Hunter $L^*$ (lightness) value: Dark ($L^* \leq 47$; $n = 28$), Intermediate ($47.1 < L^* < 49.1$; $n = 29$), and Light ($L^* \geq 49.7$; $n = 29$). Proteins soluble in low ionic strength buffer (50 mM Tris-HCl pH 8.5 and 1 mM EDTA) were extracted, digested with trypsin, and labeled with 11-plex isobaric tandem mass tag labels. Peptides were introduced to the Q-Exactive Hybrid Quadrupole-Orbitrap Mass Spectrometer and were identified and quantified with Proteome Discoverer. Data were normalized to the total ion count from each run, Log2 transformed, and median normalized. Only proteins identified in at least half the samples containing at least 2 unique peptides were included in the analysis. Non-targeted metabolome analysis was conducted on extracts (80% methanol) of each sample. Separation was conducted with a TG-5MS column (30 m × 0.25 mm × 0.25 mm). Masses between 50 and 620 m/z were scanned at 4 scans/s after electron impact ionization operating at 70 eV. All data were analyzed in R 4.1.1 using the limma package with a false discovery rate of 0.05.

Results: Differentially abundant proteins/peptides were identified ($P < 0.05$) between Dark and Light (37), Dark and Intermediate (1), and Intermediate and Light (1). Proteins/peptides identified as having greater abundance in the soluble fraction in the Dark group ($n = 19$ proteins) included calsequestrin, sarcalumenin, alpha-crystallin B chain, ubiquitin carboxyl-terminal hydrolase isozyme L3, and 14-3-3 protein gamma. Proteins/peptides with greater abundance in the soluble fraction in the Light group ($n = 18$ proteins) included glycerol-3-phosphate dehydrogenase ($NAD^+$), synaptopodin-2, nebulin, and beta-enolase. Furthermore, differentially abundant metabolites were identified between Dark and Light (22), Dark and Intermediate (3), and Intermediate and Light (5). The Light group had more ($P < 0.05$) cholesterol, nicotinamide, and sugars, including glucose-6-phosphate, glucose-6-phosphate, and mannose-6-phosphate, whereas the Dark group had more ($P < 0.05$) hypoxanthine and amino acids, including glutamic acid, serine, and threonine.

Conclusion: The differential proteins identified among the 3 lightness groups were related to energy metabolism, sarcoplasmic reticulum homeostasis, cytoskeleton, chaperonin, redox metabolism, and proteolysis. Additionally, differences in metabolome profile were identified between the different color categories. Overall, the results demonstrated that distinct molecular profiles are associated with variation in fresh pork color.

Funding Source: Funding was provided in part by the Iowa Pork Producers Association.

Keywords: metabolomics, pork color, proteomics, tandem mass tag

## 169 PREHARVEST HEALTH TREATMENT EFFECTS ON POST-HARVEST TENDERNESS, LEAN COLOR, AND ANTIOXIDANT CAPACITY

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Objectives: Our objective was to evaluate the effects of metaphylactic treatment following bovine respiratory disease (BRD) diagnosis at the feedlot on postharvest tenderness, color stability, and oxidative status.

Materials and Methods: A subset of cattle ($n = 72$) were selected for this study based on number of metaphylactic treatments in response to BRD (Control = 0 treatments; TRT1 = 1 treatment; TRT2 = 2 treatments). Cattle were evaluated daily and treated as needed based on rectal temperature (>37.5°C) and clinical illness score. Treatments included a negative control (saline), or subcutaneous administration of either florfenicol, ceftiofur, or tulathromycin. Whole blood was collected and processed for plasma at feedlot arrival, 112 d, and 245 d. On day 246, cattle were shipped to a commercial processing facility, and at 48 h postmortem, striploins from selected steers were collected, immediately sectioned into quarters, and randomly assigned to aging treatments (7, 14, 21, 28 d). A face steak was also removed from the most anterior end of each strip loin, vacuum packaged, and frozen for subsequent analyses. Following assigned aging intervals, 3 steaks were cut from each quarter, vacuum packaged, and frozen for analyses. Quarters designated to 14 d had 2 additional steaks assigned to retail display. Retail display steaks were packaged in overwrap and displayed in coffin-style cases to be evaluated for redness and percentage discoloration by trained panelists, and $L^*$, $a^*$, and $b^*$ values for 6 d. Slice shear force was evaluated on steaks representing every carcass and aging point. Furthermore, ferric reducing antioxidant power (FRAP) was determined via colorimetric assay on plasma from all 3 time points and 48 h postmortem tissue. Repeated measures and a split-plot design were used to evaluate FRAP and color evaluations, as well as tenderness, respectively. Correlation coefficients were also determined across all variables mentioned.

Results: An interaction between treatment number and hours of display occurred for steak redness ($P = 0.04$). Throughout the display period, steaks from treated cattle were consistently more red than control samples ($P < 0.05$). However, when evaluating tenderness, there were no interactions or treatment differences ($P \geq 0.29$). Still, as days of age increased, slice shear force values decreased ($P < 0.001$). In plasma and 48 h postmortem tissue, FRAP values showed an interaction between treatment number and sample timing ($P = 0.02$). At the first and final time points, antioxidant capacity in plasma samples increased as treatment number increased ($P < 0.05$). Samples evaluated at the middle time point, as well as postmortem tissue, did not differ ($P > 0.05$). Correlation coefficients showed a positive correlation between final FRAP values in plasma and redness at 0 and 6 d during retail display ($P \leq 0.01$) suggesting that as antioxidant capacity increased pre-harvest, postmortem steak redness during display also increased.

Conclusion: These data suggest that preharvest treatment of BRD may affect antioxidant capacity and oxidative stress markers in cattle, ultimately impacting meat quality during retail display. This study also implies that any reduction in usage of antimicrobials or use of alternative technologies during the feedlot period may have significant effects on meat quality.

Keywords: antioxidant capacity, retail display, slice shear force

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## 170 METABOLIC AND COLOR DIFFERENCES BETWEEN ANGUS AND BRAHMAN LONGISSIMUS LUMBORUM

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Objectives: Metabolic activity can affect the ability of a muscle to form and maintain a desirable, bright cherry-red color. Mitochondria (mt) continue to consume oxygen in postmortem muscle, thus lowering the availability of oxygen to bind to myoglobin. Mt oxygen consumption occurs through complex IV activity (cytochrome c oxidase [COX]). Lactate dehydrogenase (LDH) activity catalyzes the interconversion of pyruvate and NADH to lactate and NAD+. LDH activity toward lactate is an indicator of glycolytic metabolism, whereas LDH activity toward pyruvate can be used to demonstrate the rate of NADH replenishment. Previously, we showed that Angus *longissimus lumborum* (LL), compared with Brahman, blooms brighter at the initiation of display. Thus, our objective was to evaluate metabolic differences between Angus and Brahman LL at differing postmortem conditions and the effect on color development.

Materials and Methods: Angus and Brahman steers ($n = 14$ per breed) were harvested at the University of Florida meat lab. Samples were collected from the LL at 1 h and 14 d postmortem, frozen in liquid nitrogen, and stored at −80°C. For COX activity, 1-h pulverized samples ($n = 5$ per breed) were diluted in homogenization buffer, sonicated, and centrifuged. Reaction media with reduced cytochrome c and potassium phosphate buffer adjusted to

pH 7.0, 6.7, 6.4, 6.1, and 5.8 was plated. Activity was read following the addition of supernatant and reported as nmol/min/mg protein. For LDH activity, 1-h and 14-d pulverized samples were diluted in buffer, homogenized, and centrifuged. For LDH activity toward lactate, supernatants were plated with reaction media (NAD+), and the reaction was initiated with the addition of pyruvate. LDH activity toward pyruvate was evaluated as described for LDH activity, but with different reaction media (NADH) and substrate (lactate). Activity was reported as mmol/min/mg tissue. Data were analyzed in SAS-JMP Pro 16. COX activity was evaluated with fixed effects of breed and pH, and their interaction, whereas LDH activity was evaluated with fixed effects of breed and time and their interaction. Animal was considered a random effect.

Results: Reaction media pH affected COX activity ($P < 0.0001$). COX activity was similar between pH 7.1 and 6.4, but activity progressively decreased with lower pH. COX activity decreased > 50% from pH 6.4 to 5.8. Breed did not influence COX activity ($P = 0.24$). Brahman exhibited higher LDH activity toward lactate ($P < 0.0075$) and towards pyruvate ($P = 0.02$) compared with Angus. As expected, LDH activity decreased from 1 h to 14 d for LDH activity toward lactate ($P = 0.0023$) and toward pyruvate ($P < 0.001$).

Conclusion: The decrease in COX activity below pH 6.4 demonstrates that a decline in postmortem pH significantly hinders mitochondrial oxygen consumption. Elevated LDH activity toward lactate in Brahman evidences a greater capacity for glycolytic metabolism, whereas the increase in LDH activity toward pyruvate demonstrates an increased capacity to regenerate NADH. Thus, increased postmortem oxygen consumption coupled with a greater capacity for anaerobic metabolism suggests that elevated metabolic activity can explain why LL from Brahman, compared with Angus, blooms less efficiently upon initial exposure to oxygen.

Funding Source: USDA-NIFA AFRI 2017-67017-26468, Hatch Project FLA-ANS-006165, Florida University Scholars Program.

Keywords: color, enzyme activity, metabolism, mitochondria

## 171 EVALUATION OF DISSOLVED OXYGEN CHANGES DURING OXYMYOGLOBIN OXIDATION USING A PROBE-TYPE OXYGEN SENSOR IN VITRO

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Objectives: Oxymyoglobin is formed when oxygen ligand binds with ferrous iron in heme ring; this gives meat a characteristic bright red color. However, during oxidation, ferrous form is converted to ferric with the replacement of oxygen ligand with water. Limited technologies are currently available to evaluate oxygen level changes during oxymyoglobin oxidation. The objective of this study was to evaluate the change in oxygen level during the initial phase of oxymyoglobin oxidation using a NeoFox oxygen sensor *in vitro*.

Materials and Methods: In the current research, we utilized an *in vitro* model with purified myoglobin in order to limit other oxygen-consuming factors and the role of mitochondria. Two separate experiments were conducted due to technical limitations of the sensor. Equine metmyoglobin (pH = 5.6) was mixed with sodium hydrosulfite and filtered through a PD-10 column to obtain an oxymyoglobin solution. Both oxymyoglobin oxidation and dissolved oxygen level changes were recorded. The oxymyoglobin was brought to room temperature (22°C–24°C), and the NeoFox probe with Teflon membrane apparatus was placed in the solution to read percentage oxygen. A NeoFox fiber optic oxygen sensing system uses a fluorescence-based optical sensor to quantify oxygen level changes (Ocean Optics, Dunedin, FL). The slope of the reaction was determined from 0 min to 60 min and at various intervals for experiment 1 ($n = 6$ replications). The slope of the reaction for experiment 2 ($n = 5$ replications) was determined beginning at 120 min and at various time points between 120 and 150 min. For both experiments, the slope was determined for 300 to 500 s as the first interval and then every 500 s interval after. Oxymyoglobin changes were recorded every hour using a UV-Vis spectrophotometer for both experiments. The slopes for each experiment were separately analyzed using the GLIMMIX procedure of SAS with a nominal level of significance at $P < 0.05$. The rate of the reaction in experiment 1 and 2 was compared for the first 30 min of each experiment using the GLIMMIX procedure of SAS. Least-squares means were separated using the PDIFF option at $P < 0.05$. The mean oxymyoglobin content was determined at the beginning and end of each experiment.

Results: The initial oxymyoglobin content was 87.8% and decreased ($P < 0.05$) to 74.14% in experiment 1, whereas the oxymyoglobin content in experiment 2 initially was at 89.67% and declined ($P < 0.05$) to 69.37% in 150 min. The first interval from 300 to 500 s had the fastest decrease ($P < 0.05$) in percentage oxygen for experiment 1. There was a decrease ($P < 0.05$) in the rate of oxygen loss from 500 to 1,000 s compared with the first interval. As the reaction continued, the rate continued to decrease, resulting in slower oxygen loss compared with the first 1,000 s. However, in experiment 2, there was not a significant time effect on the rate of oxygen loss. Comparing the first 30 min of both experiments, the oxygen consumption rate was significantly higher in the first 300 to 500 s of experiment 1 compared with experiment 2.

Conclusion: In conclusion, our experiment demonstrates the oxygen consumption during oxidation of oxymyoglobin and the rate of oxygen loss was much faster initially and became constant with increased time. Furthermore, this technique has potential for study of oxygen level changes associated with mitochondria, lipid oxidation, and microbial growth.

Keywords: myoglobin, oxidation, oxygen, oxymyoglobin

## 172 COMPARISON OF THREE GOAT PROCESSING METHODS ON PROCESSING EFFICIENCY, FABRICATION YIELD, AND MEAT QUALITY OF BOER GOAT

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Objectives: Demand for goat meat in the United States has grown continuously for the last 40 y owing to the large increase in populations of people from a variety of ethnicities. However, goat carcasses are more prone to cold shortening due to less exterior fat cover compared with other livestock species, and the presence of the skin on the carcasses may better preserve body heat. Therefore the objective of this study was to evaluate the effects of 3 processing methods on goat carcasses for processing efficiency, carcass yield, and meat quality, using skin-on chill/skin-on fabrication, skin-off chill/skin-off fabrication, and skin-on chill/skin-off fabrication.

Materials and Methods: A total of 19 Boer goats ~7 mo old were harvested using one of the 3 chilling and fabrication methods with 2 replications: 1) skin-on chill/skin-on fabrication ($n = 7$), 2) skin-off chill/skin-off fabrication ($n = 6$), and 3) skin-on chill/skin-off fabrication ($n = 6$). Carcass temperature was measured initially and every 5 min during the entire chilling of carcasses, and pH was measured initially and at the end of chilling in *longissimus lumborum* (LL) and *semimembranosus* (SM) muscles. After 24 h of postmortem chilling, carcasses were fabricated into 7 primal cuts: neck, shank, shoulder, breast, rack, loin, and leg, with/without skin removal. The loin and leg primals were further fabricated into retail loin and leg chops to have LL and SM only, respectively, for analysis. Live goat weight, hot carcass weight, cold carcass weight, and primal cuts weight were recorded. For meat quality, instrumental color, sarcomere length, and total collagen were evaluated. The total harvesting and total fabrication times were also recorded for each carcass.

Results: Overall harvest time from stun to chill did not differ between the skin-on chill and skin-off chill carcasses ($P > 0.05$). As expected, the dressing percentage was higher in skin-on chill carcasses than skin-off chill carcasses ($P < 0.01$), regardless of fabrication method. The chilling rate did not differ between the skin-on and skin-off carcasses ($P > 0.05$). It was interesting to note that the pH of the SM muscle displayed a faster decline rate than LL in the temperature zones between 21°C and 4.4°C; however, the ultimate pH was similar between the 2 muscles ($P > 0.05$). The skin-on chill/skin-off fabrication group took longer to fabricate than that of the other 2 treatments ($P < 0.01$), and the amount of useable product after fabrication was higher in the skin-on fabrication group than the skin-off groups ($P < 0.01$).There was no difference among treatments and muscles for redness and lightness ($P > 0.05$), but skin-on chill SM displayed a more yellow color than skin-off chill SM, regardless of fabrication method ($P < 0.05$). The sarcomere length among treatment groups did not differ ($P > 0.05$), whereas a longer sarcomere length was found in SM than LL ($P < 0.01$). As expected, the total collagen content in skin-on LL cuts was higher than those in the skin-off cuts, regardless of chilling method ($P < 0.05$), whereas no total collagen difference was found for SM ($P > 0.05$).

Conclusion: Based on the results of this study, the processing efficiency and meat quality of skin-on chilled goat meat appears to be either better or the same as the skin-off chilled goat meat. Additional research is required to evaluate microbial safety, sensory attributes, and industrial implementation of skin-on goat processing in the United States.

Funding Source: This work is supported by non-Land-Grant College of Agriculture Award No. 2021-70001-34777 from the USDA National Institute of Food and Agriculture.

Keywords: dressing yield, meat quality, processing efficiency, skin-on goat

## 173 INTEGRATING PROTEOMICS AND METABOLOMICS PROFILING TO UNDERSTAND LEVELS OF MUSCLE DARKENING IN BEEF

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Objectives: The application of high-throughput omics approaches, specifically proteomics and metabolomics, in meat science research has helped probe molecular changes associated with meat quality. Several studies have utilized a single platform to understand biochemical changes. Limited research has integrated proteomics and metabolomics approaches to understand muscle darkening in beef. The objective was to integrate proteomics and metabolomics expression profiles data sets of dark beef at slightly darker (SpH; pH = 5.70) and dark-cutting beef at high pH (HpH; pH 6.4) compared with normal-pH beef (NpH; pH = 5.57) to understand the threshold for muscle darkening in beef.

Materials and Methods: The different levels of darkened *longissimus lumborum* muscles were collected within 48 h postmortem on 2 separate occasions (NpH and SpH and NpH and HpH). Loins were sliced into 2.5 cm steaks and randomly placed on foam trays, wrapped with polyvinyl packaging film, and allowed to bloom for 1 h. Steaks were utilized to measure pH, surface color, proteomic, and metabolomics analysis. $L^*$, $a^*$, and $b^*$ were recorded using a HunterLab MiniScan spectrophotometer. Muscle samples were also subjected to quantitative proteomics analysis using liquid chromatography-tandem mass spectrometry–based proteomics and metabolomics profiling via a non-targeted gas chromatography-mass spectrometry. Surface color data were analyzed using the Mixed Procedure of SAS. Proteomics and metabolomics data were analyzed using several bioinformatics approaches, and the changes in protein and metabolite expression profiles were considered significant at a false discovery rate of $< 0.05$.

Results: SpH and HpH were 11.7% and 27.4% darker (lower $L^*$ values) than NpH, respectively ($L^*$ values—NpH = 43.2, SpH = 38, and HpH = 31.1). Metabolomics analysis indicated that 12 out of 13 metabolites related to glycolytic and tricarboxylic pathways showed no difference ($P > 0.05$) between SpH and NpH, whereas 12 out of 13 metabolites were different ($P < 0.05$) between HpH and NpH. Interestingly, 7 out of 18 proteins related to glycogen and mitochondrial metabolism differed between SpH and NpH, and 14 out of 18 differed between NpH and HpH. Therefore, results suggest that proteins involved in glycogen and mitochondrial metabolism were more affected by pH change than metabolites.

Conclusion: Integrating protein and metabolite profiling show pH-dependent effects on muscle darkening. Therefore, characterizing protein and metabolites will help increase understanding of the threshold for developing muscle darkening.

Funding Source: United States Department of Agriculture and National Science Foundation.

Keywords: meat color, metabolomics, muscle darkening, proteomics

# Technical Summaries

## *174 FIGHTING CHILDHOOD HUNGER IN COLORADO*

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Objectives: Childhood food insecurity is a significant issue in the United States. Approximately 224,000 children in Colorado struggle with weekend food insecurity, which can adversely impact their ability to learn. One innovative solution is a food backpack for children to take home on weekends. These backpacks contain easily prepared, shelf-stable items but can lack sufficient protein.

Materials and Methods: The Beef Sticks for Backpacks charity was founded to provide a tasty, no-preparation protein source for weekend backpacks in Colorado at no cost to the to the backpack programs. The charity approached Colorado State University, Global Food Innovation Center (GFIC) with the initial request to make 750 beef sticks weekly. A mild formulation with no allergens was used so that any child could enjoy it. The meat block is stuffed into a 17-mm collagen casing producing a 28-g, 18-cm stick. Encapsulated citric acid is used to release the acid during thermal processing to reduce the pH. The thermal processing cycle consists of 9 phases that smokes, fully cooks to 70.5°C, and dries the product lowering the water activity. The combination of acidification, fully cooking, and drying results in a shelf-stable product.

Results: The program was immediately successful, and demand rose to 4,000 sticks per week, resulting in many manufacturing challenges. The GFIC was using a single-chamber vacuum sealer that could package 12 sticks/45 s, limiting efficiency. The addition of a Multivac R081 Roll-stock machine yielded 64 individual sticks/min. Labor standards for each step were created. As production grew, creative solutions were found to address each rate limiting step. A pilot-sized Cozzini 68-kg blender is used for mixing. A Handtmann VF 628 industrial stuffer is utilized to form the product into collagen casings. Casings, spices, ingredients, smoke chips, and PPE were acquired as needed to produce the increasing volume through a particularly challenging time due to supply chain shortages. Chemical analyses of the product include fat content, water activity, and pH. Microbiological testing of the product and environment monitoring are routinely conducted and trended to ensure product safety. Through charitable donations, the cost to produce the beef sticks was reduced, and currently, labor is the only fixed cost.

Conclusion: The GFIC currently manufactures 16,000 beef sticks weekly with distribution to 11 Colorado counties. Colorado State University students produce the beef sticks

and learn the concepts of raw material supply, inventory control, scheduling, meat processing, cooking, meat chemistry, microbiological testing, food safety, packaging, sanitation, and Food Safety Inspection Service regulations at a level not typically experienced at a university. The project generates over 150 paid undergraduate student employee hours per week, promoting true hands-on learning. Beef Sticks for Backpacks will increase their reach in fall 2022 distributing 20,000 beef sticks per week. The goal is to create a course and internship around the beef stick project to increase student engagement and interaction with the charity and the business side of the project. This project is a unique example of collaboration between the industry, the charity, and a land grant university to create innovative solutions to real world problems.

Keywords: None

## 175 ANTIMICROBIAL EFFICACY OF BEEF HIND HOCK VACUUM INTERVENTION ON THE REDUCTION OF APC AND ENTEROBACTERIACEAE

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Objectives: Mitigating and reducing cross contamination from hide to carcass during the beef de-hiding process continues to be a rigorous responsibility in the meat industry. Hind Hock Vacuums (Jarvis model HS-2) utilize hot water (180°F, 3.5 gal/min) and vacuum (356 mm Hg) to reduce debris and microbial contamination on carcass hocks that result from de-hiding. The objective of this study was to determine the efficacy of reducing aerobic plate count (APC) and Enterobacteriaceae on the right and left beef hind hocks after hock vacuum treatment.

Materials and Methods: Sponge samples (3M Sponge-Stick with 10 mL Letheen Bouillon) were taken immediately before hock vacuum treatment ($n = 15$) and within 10 s after the intervention ($n = 15$) to allow water to drip off and surface temperature to cool down for both the right and left hocks. During sample collection, it was observed that the incoming water was 180°F–182°F, 39–45 psi, with 8-s contact time by both right and left vacuum operators. Samples were sent to IEH Lab for APC and Enterobacteriaceae analyses. Results were log converted, and statistical analysis was performed using regression analysis ($P = 0.05$) on Excel (Microsoft 365 version 2111).

Results: The study demonstrated that both hock vacuums resulted in significant ($P < 0.005$) reductions of both APC and Enterobacteriaceae (Log CFU/hock) on average. The average APC on untreated hock was 3.20 log and 3.44 log on the right and left hocks, respectively. After hock vacuum treatment, the average APC observed was 2.64 log and 2.23 log for the right and left hocks, respectively. The average Enterobacteriaceae counts on untreated hock was 1.92 log on both the right and left hocks. After hock vacuum treatment, the average Enterobacteriaceae counts observed were 0.73 log and 0.55 log for the right and left hocks, respectively. Treatment from the right hock vacuum resulted in significant reductions of 0.56 log APC and 1.19 log Enterobacteriaceae. Similarly, the left hock vacuum resulted in 1.21 log reduction of APC and 1.36 log reduction of Enterobacteriaceae.

Conclusion: The use of the hind hock vacuums has demonstrated to be an efficacious intervention that reduces APC and Enterobacteriaceae on beef hind hocks after the de-hiding process.

Keywords: aerobic plate count, beef, Enterobacteriaceae, hide, hock vacuum

## 176 EFFICACY OF PEROXYACETIC ACID SPRAY ON THE REDUCTION OF APC AND ENTEROBACTERIACEAE ON BEEF HIDE

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Objectives: Cleanliness of beef hide prior to the de-hiding process plays a major role in beef carcass contamination. Treatment of beef hide with peroxyacetic acid (PAA) may reduce bacterial counts prior to the de-hiding process, minimizing carcass contamination. The objective of this study is to determine the efficacy of reducing aerobic plate count (APC) and Enterobacteriaceae via hide spray that utilizes 250–350 ppm concentration of PAA on the round, hock, and belly areas on the hide of incoming beef cattle.

Materials and Methods: Following captive bolt stunning, beef cattle were sprayed on the round, hock, and belly areas with PAA (250–350 ppm) hide spray ($n = 15$) or without ($n = 15$) hide spray. Sponge samples (3M Sponge-Stick with 10 mL Neutralizing Broth) were taken immediately after the first cut of the de-hiding process on the right inside round just lateral of the initial center cut on the rump. Samples were sent to IEH Lab for APC and Enterobacteriaceae analyses. Results were log converted, and statistical analysis was performed using regression analysis ($P = 0.05$) on Excel (Microsoft 365 Version 2111).

Results: The study demonstrated that application of the PAA hide spray resulted in significant ($P < 0.05$) reductions of both APC and Enterobacteriaceae on average. APC was reduced from 5.51 Log CFU/mL on untreated hide to 4.82 Log CFU/mL with hide spray treatment. The average Enterobacteriaceae count without treatment was 4.37 Log

CFU/mL, which was reduced to 3.41 Log CFU/mL after treatment.

Conclusion: The use of the PAA hide spray has been demonstrated to be an efficacious intervention that reduces APC and Enterobacteriaceae on incoming beef hides before the de-hiding process.

Keywords: aerobic plate count, beef, Enterobacteriaceae, hide, peroxyacetic acid

## 177 NOVEL TIME LAPSE VIDEO SURVEILLANCE FOR COLOR SCORING

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Objectives: Appearance is one of the top factors that determines consumers' perception of quality and significantly influences purchasing decisions. When beef is under retail display, it will oxidize and change from oxymyoglobin to metmyoglobin. Consumers typically prefer a bright cherry-red color and associate it with freshness while discriminating against a dark red or brown color. Color scoring is widely utilized to help determine when a consumer would discriminate against a product. The objective of this study was to assess the ability to utilize time-lapse video technology to color score the *longissimus lumborum* (LL) muscle.

Materials and Methods: A steak from a USDA Low Choice strip loin (LL) aged 21 d postmortem was utilized. It was packaged in a polyvinyl chloride overwrap tray and placed in retail display under time-lapse video surveillance for 6 d. Time-lapse video surveillance was taken using the Lapse It© app from the Apple App Store. The steak was placed in the retail case under the iPad to take clear and consistent pictures. The app was set to take a photo every hour and was checked periodically until the steak was fully discolored. A 7-member trained panel, all of whom passed the Farnsworth-Munsell 100-Hue Test, evaluated the steak for visual color, surface discoloration, and overall acceptability using a hedonic scale for each. Throughout the display, trained panelists evaluated the steak, and a separate trained panel evaluated the steak from the video surveillance. Both panels evaluated the steak at the same time each day. Visual color was rated using a hedonic scale of 1–8 (1 = extremely bright cherry red and 8 = extremely dark red), surface discoloration was rated using a scale of 1–6 (1 = no discoloration, 0%, and 6 = extensive discoloration, 81%–100%), and overall acceptability was rated using a scale of 1–7 (1 = very definitely would not purchase and 7 = very definitely would purchase). At the end of 6 d, the trained panel deemed the product to be unacceptable, 81%–100% surface discoloration, and they stated they would no longer purchase the product. Microsft Excel was used to compare means of the color score results on each day, while the CORR procedure of SAS was used to determine the correlation between in-person and video color scores.

Results: There was no significant difference ($P > 0.05$) between in-person and video color scoring for all parameters, and the correlation coefficient was $r = 0.99$. However, there was a difference between means for the visual color on each retail day. Everyday color score decreased until day 5 and plateaued between day 5 and 6 on the hedonic scale. After the third day of retail display, the steak was more discolored each day. Moreover, the trained panelists stated they would no longer purchase after day 4, at 21%–40% discoloration. Studies have shown that consumers begin to discriminate against meat with 20% metmyoglobin formation (Macdougall, 1982). This reflects the discrimination seen with the trained panelists.

Conclusion: Overall, as time in retail display increased, both in-person and video panelists indicated a similar change in color and acceptability. The current study suggests that the use of time-lapse video may have the potential to characterize color changes over time, but further research should be conducted to validate the method.

Keywords: color score, meat color, time-lapse, visual analysis

## 178 EVALUATION OF COOKING TIME OF GROUND BEEF FROM DIFFERING FAT PERCENTAGES AND SIZES IN A RATIONAL© OVEN

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Objectives: Cooking impacts basic traits related to consumer preferences such as flavor, tenderness, color, and appearance (Sepulveda, 2019). Forced-air convection oven is one of the most popular methods of cooking steaks for both sensory and instrumental evaluations (Yancey, 2011). Moreover, the Rational© convection oven is popular in food service due to its ability to handle a large load size with excellent uniform results across all the racks (Rational©). Thus, the objective of this study was to better understand the evenness of cooking location in a Rational© oven of ground beef patties from varying fat percentages and patty sizes.

Materials and Methods: Chubs of ground beef from 3 fat percentages (93/7, 81/19, and 73/27) were obtained from a commercial packing facility. Four 4.54-kg chubs were combined to make a composite sample for each fat percentage. Proximate analysis was conducted to ensure product met target percentages. From the composite sample, 30 patties were formed to 3 target sizes (226 g 2.54 cm thick, 150 g 1.91 cm

thick, and 113 g 1.42 cm thick) of each fat percentage ($n = 30$ patties/size/fat). All patties of similar weight and fat percentage were cooked in one cycle; 6 patties were placed on 5 cooking racks (top to bottom) in 6 rack locations (left back, right back, left center, right center, left front, right front) and cooked to a final target internal temperature of 71°C in a Rational© SCC WE 102G oven set to 204.4°C with 0% humidity. Temperature was monitored using an over core temperature probe in one centrally located patty. Once final temperature was reached, cook time was recorded, patties were immediately removed from the oven, and internal temperature was recorded. Initial and final cooked weight was recorded to determine cook loss percentage. Patties were sliced parallel to the surface to expose the internal surface, where a trained panel evaluated internal cooked color and objective color measurements were taken using a HunterLab Miniscan Spectrophotometer.

Results: Final cook temperature was higher ($P < 0.05$) on the top 2 layers and higher across the back of the oven for patties of all sizes and fat percentages. Internal cooked color was the least red ($P < 0.05$) based on trained panelist scores for patties cooked on the top layer. Moreover, 226-g patties from the 81/19 blend were scored the least red ($P < 0.05$). Following a similar trend, internal $a^*$ values were lower ($P < 0.05$) in patties cooked on the top layer. Cook loss percentage increased ($P < 0.05$) as patty weight and fat percentage increased. Additionally, cook loss percentage was higher ($P < 0.05$) for patties cooked on the top layer than any other. As expected, the 93/7 blend took the longest ($P < 0.05$) to cook as well as the 226-g patty.

Conclusion: In conclusion, understanding your forced-air convection oven make and model is important when conducting trials for food service and research to ensure even and consistent cooking.

Keywords: None