# Monday, June 22, 2009

## POSTER PRESENTATIONS

### : Processing, Packaging and Safety

**5 Prevalence of water binding ingredients in processed meat and poultry products.** B. L. Goehring* and E. A. E. Boyle, *Kansas State University, Manhattan*.

Water binding ingredients (WBI) are an important component of many processed meat and poultry products. To determine the type and prevalence of WBI currently used in meat and poultry products, an online review was conducted between June 25 and October 30, 2008. Nine companies that were ranked in the May 2007 *Red Meat Elite* or industry segment by Meatingplace magazine or by Watt Poultry USA, February 2008 as a top poultry company were selected based on access to online ingredient statements. The incorporation of WBI in 625 processed meat and poultry products was evaluated by reviewing online ingredient statements and from these a list of 39 WBI was identified. Products were categorized by protein source and product category. Protein sources included chicken, turkey, beef, pork, or any combination of two or more protein sources. Products were also assigned to one of 11 categories including bacon, deli meats, ham, hot dogs, prepared entrées, snacks, breakfast/dinner sausage, summer sausage, whole bird, whole muscle and other. Of the 625 products evaluated, 514 (82%) listed a WBI. Ingredient statements for 236 turkey products were reviewed of which 212 (89%) contained one or more WBI. Of the 33 chicken products reviewed, 32 (97%) contained one or more WBI, while 150 of the 191 (78%) pork products reviewed contained one or more WBI. Processed beef products contained the fewest WBI with 52 out of 73 (71%) products listing WBI in the ingredient statement. There were 92 products formulated with multiple protein sources, of which 68 (74%) products contained WBI. The widest variety of WBI was found in turkey products as they contained 29 (74%) of the 39 WBI identified, followed by beef or a combination of protein sources with 17 (44%), and chicken or pork with 12 (31%) WBI. Based on protein source, sodium phosphate followed by modified food starch or maltodextrin were the most commonly used WBI in this review, consisting of 85% and 22%, respectively for products listing WBI. When WBI were evaluated based on product category, 100% of hot dog ingredient statements (22 products) listed WBI. Of the 240 deli meat products reviewed, 232 (97%) ingredient statements listed WBI, followed by 93 out of 97 (96%) whole muscle products, 18 out of 19 (94%) whole bird products, 32 out of 35 (92%) hams, 15 out of 17(88%) bacon products, 34 out of 59 (58%) snack products, 11 out of 19 (57%) other category products, 54 out of 106 (51%) breakfast/dinner sausages, and 0 of 11 (0%) summer sausage products. Sodium phosphate also was the most common WBI across all product categories with the exception of the snack category (maltodextrin) and summer sausage. This demonstrates that while a variety of WBI are used in processed meat and poultry products, it is evident that sodium phosphate was the most commonly used WBI, although this review was limited to online ingredient statements of traditional processed meat and poultry products from selected companies.

**Key Words:** water binding ingredients, processed meat and poultry products

**6 Phosphate type affects the quality of injected catfish fillets.** S. Kin[1], M. W. Schilling*[1], B. S. Smith[2], J. L. Silva[1], V. Jackson[1], and T. J. Kim[1], [1]*Mississippi State University, Mississippi State*, [2]*John R. White Company, Birmingham, AL*.

Phosphates are utilized to reduce oxidation, freezer-burn, and drip loss in fresh and frozen fish. Sodium tripolyphosphate is a commonly-utilized phosphate in catfish marinades, but phosphate blends are becoming more popular based on their solubility and functionality in meat product formulations. However, minimal research has been reported pertaining to their functionality in raw, tray-packed, refrigerated catfish fillets. The objective of this experiment was to determine the effects of using sodium tripolyphosphate and various agglomerated phosphate blends on the quality of refrigerated catfish fillets that were enhanced through multineedle injection. A control (not injected with phosphate and salt), sodium tripolyphosphate (STP), agglomerated blends of sodium phosphates (AGSP), poly- and pyrophosphates (AGPP), polyphosphates (AGP), and potassium and sodium polyphosphates (AGPSP) were utilized as treatment variables. Catfish fillets were injected to 115% over green weight so that there was 0.5 % salt and 0.45 % phosphate in the finished product. Catfish fillets were then tray-packed and stored at 4 C for 1, 4, 8 and 11 days. Fillets were evaluated for solution pick-up, surface color, pH, tenderness, cooking loss, and shelf-life. A randomized complete block design with three replications was utilized to determine differences ($P<0.05$) among treatments.
Fillets treated with AGSP had greater ($P<0.05$) solution pick-up than STP, AGPP and AGPSP. In addition, all phosphate treatments increased yield based on green weight when compared to the control, but AGSP had higher ($P<0.05$) yields than all other phosphate treatments. This increase in yield could be partially due to the higher pH ($P<0.05$) of the AGSP treatment when compared to all other treatments as well as the multifunction of mono-, di-, tri-, and polyphosphates present in AGSP. All phosphate treatments, with the exception of AGPP, yielded lower ($P<0.05$) fillet CIE L* values (were less pale) than the control treatment. In addition, the AGSP treatment had the lowest ($P<0.05$) CIE L* value of all treatments, which is probably due to the higher pH and yields. All phosphate treatments increased ($P<0.05$) fillet tenderness when compared to the control, but no differences existed ($P>0.05$) among phosphate treatments. In addition, no differences ($P>0.05$) existed among the phosphate and control treatments with regards to the raw odor of fillets on day 4 and 8, but phosphate treatments, with the exception of AGP, yielded a lower ($P<0.05$) off-odor score than the control fillets on day 11. These sensory data revealed that all samples were spoiled at some point between day 8 and 11. AGPP fillets had lower ($P<0.05$) psychrotrophic plate counts (PPC) than the control at each storage time while other phosphate treatments had lower ($P<0.05$) PPC than the control on day 8. However, all samples had PPC greater than $10_8$ cfu/g at day 11 of storage, indicating that catfish fillets for all treatments also spoiled at some point between day 8 and 11. All phosphate treatments improved the quality of tray-packed, refrigerated catfish fillets that were enhanced through multineedle injection. However, AGSP also increased fillet pH, optimized yield and improved color.

**Key Words:** catfish fillet, multineedle injection, agglomerated phosphate blend

**7 Effect of alternative salts on chicken breast meat flavor and sodium concentrations.** K. P. Lopez*, J. M. Behrends, and M. W. Schilling, *Mississippi State University, Mississippi State*.

Marination is often used in the meat industry to enhance flavor and tenderness. The need to find alternative salts and ingredients to improve meat quality characteristics and lower sodium levels continues to be a major priority for the industry. The objective of this study was to evaluate alternative gourmet salts (n=5) and determine their effect on sensory properties and sodium concentration. The salts included Bolivian Rose Salt (BRS), Himalayan Pink Sea Salt (HPS), Sel Gus De Guerande by le tresor (SGDG), Sonoma Gourmet Salt (SGS), and Table Salt (TS). Each salt was added to the marinade in the amount of 1% on a finished product basis (FPB) . In addition, sodium tripolyphosphate was included in the marinade at a level of 0.49% (FPB). No other ingredients were added to the water, salt, and phosphate marinade. Broiler breasts (4.5 kg) were enhanced to 120 % green weight for each marinade treatment, and there were 3 replications for each treatment on each processing day (n=2). To determine yield, the weight of breast meat and marinade were recorded prior to vacuum tumbling. Each treatment was vacuum tumbled (137 kPa) for 17 min and then removed from the tumbler and weighed to determine total marination pickup. Breast fillets were individually quick frozen and labeled accordingly. Breast fillets (n=30) were minced to measure the sodium level (AOAC Method number 935.47). A trained descriptive panel (n=8) evaluated 6 samples in each panel (n=15) for the following sensory attributes: chicken flavor, roasted, savory, saltiness, soapy, musty, earthy, beachy, chemical, metallic, cardboard, sweet, citrus, brothy, juiciness and tenderness. There was no difference ($P>0.05$) in sodium concentration among treatments. The mean sodium concentration in the samples was 472 mg/100g. There were no differences ($P>0.05$) among treatments with respect to tenderness and juiciness. In addition, there were no differences ($P>0.05$) in chicken flavor, chicken roast, savory, saltiness, soapy, musty, beachy, chemical, metallic, cardboard, sweet, citrus, and brothy flavor among treatments. However, there was a tendency ($P=0.0693$) for SGS-treated broiler breasts to have more savory flavor than broiler breasts that were enhanced with BRS. Results indicate that the different treatments had a similar effect on broiler breast meat with respect to flavor and sodium content, but further research should be performed using variable amounts of salt in the final product to determine the effect of salt concentration on sensory quality and sodium concentration for the different salt types.

**Key Words:** alternative salts, sensory properties, broiler breast meat

**8 Antioxidant effects of dried plum powder in turkey breakfast sausage.** R. M. Merrill* and W. N. Osburn, *Texas A&M University, College Station*.

Consumer demand for convenient and low cost meat products has resulted in the development of low-fat sausage products containing alternative protein sources, such as mechanically separated turkey meat (MSTM). Products containing MSTM are susceptible to lipid oxidation due to stress and aeration during machine separation leading to undesirable sensory properties. Antioxidants, especially those of natural origin, may be used to inhibit lipid oxidation. Our objective was to evaluate the antioxidant activity of dried plum powder (DPP) compared to rosemary extract (RE)

in low fat (3.5%) turkey breakfast sausage. Batches were formulated with 80% turkey breast and 20% MSTM to produce a 13.61 kg meat block with either 3% DPP, 0.05% RE, or 3% DPP combined with 0.05% RE (DPP/RE) added, while the control (C) had no added antioxidant. Edible collagen casing sausage links (19 mm) weighing ~28 g were assigned to multiple shelf-life treatments: (RR) packaged raw in styrofoam trays overwrapped with polyvinyl chloride film (6°C/0, 3, 6, 9 days), (RF) packaged raw in interwoven paper in plastic lined cardboard boxes and frozen (-23°C/0, 7, 14, 28, 56 days), and (PF) precooked (74°C) and frozen (-23°C/0, 7, 14, 28, 56 days). Sausages were analyzed for pH, color (CIE L*, a*, b*), lipid oxidation, microbial growth, sensory attributes, reheat yields and shear force. The 2-thiobarbituric acid reactive substance (TBARS) values (mg malonaldehyde/kg of meat) for RR samples were not different ($P>0.05$) on days 0-6, although on day 9, C and RE had lower ($P<0.01$) TBARS values than DPP samples. All TBARS values were greater than 1 on day 6 and were considered rancid. TBARS values for RF DPP (0.43) and DPP/RE (0.38) were lower ($P<0.05$) than C (0.58) and RE (0.56) up to 56 days of storage. The PF DPP and DPP/RE had lower TBARS values ($P<0.01$) than C and RE samples on days 14, 28, and 56. External and internal L* values for RR ($P<0.0001$/0, 3, 6 days), RF ($P<0.05$) and PF ($P<0.01$) samples containing DPP were darker compared to C and RE samples. Redness values for RR and RF, C and RE were higher ($P<0.05$) than samples containing DPP, however the PF DPP links had higher a* values than C and RE ($P<0.01$) at 0, 7, and 28 days of frozen storage. DPP samples from each storage type had higher b* values overall. Descriptive sensory data indicated differences ($P<0.05$) between RF and PF sausages in springiness, juiciness, cohesiveness, cooked turkey lean, cooked turkey fat, plum, cardboard, and warmed over flavor. Precooking, freezing and reheating sausage links appeared to slightly decrease overall sensory attributes, with a noticeable decrease in juiciness and slight increase in warmed-over flavor, compared to RF links cooked prior to serving. Samples containing DPP had higher ($P<0.0001$) values for plum and sweet tastes, and lower ($P<0.02$) values for spice complex when compared to C and RE. The addition of 3% DPP alone and combined with 0.05% RE for use as an alternative natural antioxidant suppressed the effects of lipid oxidation while maintaining acceptable sensory attributes over long term frozen storage when compared to RE and C sausage links. It was also observed that DPP darkened the external and internal sausage link color compared to RE and C links.

**Key Words:** antioxidant, dried plum, turkey sausage

**9 Lowering sodium tripolyphosphate usage in beef enhancement brines with 1% ammonium hydroxide.** A. N. Parsons*, D. L. VanOverbeke, and C. A. Mireles DeWitt, *Oklahoma State University, Stillwater*.

The objective of this research was to reduce phosphate usage in beef enhancement brines in order to minimize additives having negative health implications for some consumers, while maintaining high quality meat standards. Ten paired Select striploins, (n=20) were randomly chosen and injected with either a control brine containing 4.5% sodium tripolyphosphate, 3.6% NaCl, and 1% Herbalox HT-S or a treatment brine containing 1% ammonium hydroxide solution, 1% sodium tripolyphosphate, 3.6% NaCl, and 1% Herbalox HT-S. Steaks, after 4 d storage in dark at 4°C, were selected randomly on days 0, 7, and 14 of retail storage to measure purge, cook yield, pH, L*a*b* color, shear force, aerobic plate counts, anaerobic plate counts,

composition, TBARs, sensory taste panel, and visual color evaluation. There was not a significant difference between the control and treatment in the following measurements: pH, purge, and shear force ($P > 0.05$). There was no significant difference between the control and treatment in any of the sensory taste panel attributes: initial juiciness, sustained juiciness, initial tenderness, connective tissue, overall tenderness, beef flavor, salty flavor, pepper flavor, or ammonia intensity ($P > 0.05$). Differences in cook loss were not seen until day 19. In the overall color score, the control was more desirable than the treatment from day 7 retail until the end of the study ($P < 0.05$). The control had lower microbial counts than the treatment in both the aerobic and anaerobic plate counts ($P < 0.05$). Differences between treatment and control steaks were minimal, except after day 7 significant differences in color started to emerge with the control performing better. The study demonstrates that the phosphate level used in meat enhancements can be significantly reduced with the aid of ammonium hydroxide as an alkaline processing aide.

**Key Words:** ammonium hydroxide, meat enhancement, beef select striploins

**10 Effects of sodium lactate and acetic acid derivatives on the quality and sensory characteristics of hot-boned pork sausage patties.** E. M. Bradley*, J. B. Williams, M. W. Schilling, C. Crist, S. Yoder, P. C. Coggins, and S. G. Campano, *Mississippi State University*, *Mississippi State*.

The objective of this study was to evaluate the effects of sodium lactate and acetic acid derivatives on the color retention, microbial growth (TPC), oxidation (TBARS), and sensory attributes of hot-boned pork sausage patties stored under retail store display conditions over time. Lactate and acetic acid were used since these ingredients have proven to be effective microbial inhibitors that have potential antioxidative characteristics. Culled sows were harvested and the resulting boneless meat was ground and separated into 20 pound batches prior to formulation with the following treatments: (a) 2.5% sodium lactate 60% solids (L), (b) 2.5% buffered vinegar pH 6.5-8.0 (V), (c) 2.5% sodium lactate and vinegar 52/ 48% mixture (LV), (d) a control with 0.02% BHA/BHT (C), and (e) negative control without additives (NC). All batches received regular sausage seasoning and 3% warm water. Treatments were stuffed into tubular plastic film and frozen overnight at -23°C prior to being sliced into patties and packaged on polystyrofoam trays that were overwrapped with plastic film. Packages were placed in a simulated retail lighted case condition and held at 0 to 1°C for up to 18 days. The experimental design was a randomized complete block with three replications in a 2-way factorial structure. Means were separated, when significant, using the Least Significant Difference (LSD) procedure at a significance level of $P<0.05$. L* (lightness) was not different ($P>0.05$) among treatments when averaged over time. LV preserved redness (a*) over time (day 16 and 18) when compared to NC ($P<0.05$) and C ($P<0.01$) treatments. LV and V had lower ($P<0.05$) microbial counts when compared to C and NC, and the LV treatment had lower ($P<0.05$) microbial counts on days 14, 16, 18 as compared to C and NC products. There was no difference ($P>0.05$) among treatments in oxidation as measured by TBARS analysis, but TBARS values did increase ($P<0.05$) over time. There was no cooked yield percentage difference ($P>0.05$) among the treatments. Trained sensory panelists ($n = 6$) described the sausage products with 13 different descriptors, but minimal practical differences existed among treatments with respect to these descriptors for the first 14 days of the

study. However, expert sensory analysis revealed that C and NC ($P<0.05$) and had more off flavor than the L and LV treatments on day 17. Overall acceptability of day 17 LV and L treatments were not different ($P>0.05$) from all day 14 treatments, but the V and NC treatments were less acceptable ($P<0.05$) than day 14 treatments. These results reveal that the L and LV sausage patties retained better sensory acceptability and microbial quality from day 14 through day 17 as opposed to other treatments. Additionally, sausage patties with 2.5% LV maintained color (redness) and overall acceptability throughout 17 days of shelf-life when held at 0 - 1°C under lights as compared to only 14 days for C and NC treatments.

**Key Words:** pork sausage, sodium lactate, vinegar

**11 Effects of transglutaminase and mungbean powder on the functional and textural properties of low-fat/salt pork sausages.** H. C. Lee* and K. B. Chin, *Chonnam National University, Department of Animal Science, GwangJu, Korea.*

Since the demands for the healthier-food and well-being type of foods are increased, many studies have been performed to develop low-fat/salt meat processing technology. Transglutaminase (TG) is an enzyme that catalyzes cross-linking reactions between lysine and glutamine residues of protein and a good binding agent for enhancing textural properties of low-fat/salt pork meat products (<3% fat and <1% salt; LFSPMP). However, the addition of TG to reduced-salt meat products may decrease the products yield and therefore, hydrocolloids with water holding capacity could enhance cooking yield of TG-induced meat products. Thus, this study was aimed to evaluate various levels of mungbean (MB) powder and TG (1%) on the product characteristics of low-fat/salt pork sausages (LFSPS). pH, proximate compositions, Hunter color values, cooking yield, expressible moisture and textural properties were measured. Since the interactions between TG and MB level were not significant in all parameters ($P>0.05$), data were pooled and expressed by TG and MB level, respectively. The addition of TG improved most textural properties, but decreased pH and cooking yields of LFSPS. When an MB level higher than 1.2% was added to the sausage mixture, it reduced the expressible moisture and increased textural springiness. These results indicated that the addition of MB (> 1.2%) could enhance water binding ability and textural properties of LFSPS and it may be used as water binding agents in TG-mediated meat products.

**Key Words:** low-fat/salt pork sausage, mungbean, transglutaminase

**12 Rheological and thermal properties of mixed myofibrillar protein and pea protein isolate systems.** K. K. Agyare*[1], J. P. D. Wanasundara[2], and P. J. Shand[1], [1]*University of Saskatchewan, Saskatoon, SK, Canada,* [2]*Agriculture and Agri-Food Canada, Saskatoon, SK, Canada.*

Field pea (*Pisum sativum* L.) is an important legume extensively produced in the province of Saskatchewan, but utilization of its protein-based ingredients in formulated food applications is limited. However, pea-protein products are reported to exhibit comparable and complementary functionality to homologous soybean-protein products, and may be an alternative source of

seed/legume protein for food applications that employ soybean protein.
Our objective was to evaluate the effect of pea-protein isolate (native and commercial pea protein isolate) addition to myofibrillar protein (MP) on the gelation and thermal properties of the mixed MP and pea protein system. Native pea protein isolate (PPIn) was prepared in the laboratory from field pea concentrate obtained by air classification (Parrheim Foods, Saskatoon, SK), by extracting with a neutral buffer containing 0.5 M NaCl, followed by isoelectric precipitation (pH 4.5), and then adjusting the pH to 7.0 before lyophilizing. Commercial food-grade pea protein isolate (PPIc, Propulse™) was donated by Nutri-Pea Limited (Portage la Prairie, MB). Myofibrillar protein (MP) was prepared from trimmed pork picnic shoulder meat (24–36 h postmortem). The MP (6.0% protein) was mixed with 6% pea protein isolate (in the ratio of 1:1 and 3:1) in 50 mM phosphate buffer (pH 6.5) containing 0.6 M NaCl. Gelation was evaluated by dynamic oscillatory rheology and thermal properties by differential scanning calorimetry. The mixed MP and pea protein isolate systems exhibited significantly ($P < 0.05$) lower rigidity due to elastic response (storage modulus of MP/PPIn was ~340–1200 Pa, and MP/PPIc was ~480–1650 Pa) at the final heating temperature (95°C) when compared with MP alone (storage modulus ~2300 Pa). However, native pea-protein isolate (PPIn) was less effective in promoting the elastic properties of MP when compared with commercial pea-protein isolate, presumably due to the high denaturation temperature of native pea globulins (~106°C) in the presence of 0.6 M NaCl. MP exhibited one main endothermic transition with peak maximum temperature ($T_m$ ) of ~62°C, corresponding to myosin denaturation, and a minor endotherm attributed to actin. In the mixed MP/PPIn, $T_m$ of myosin remained unchanged (~62°C), PPIn (native pea globulins) exhibited two transitions (~89 and 106°C) and $T_m$ of the main endotherm was ~106°C. These results suggest minimal interaction between MP and native pea globulin proteins (PPIn), and that denatured pea-protein isolate (PPIc) addition may be more effective in formulated meat products where particle binding is important.

**Key Words:** rheology, thermal properties, pea protein isolate

**13 Antioxidant effect of curry leaf (Murraya koenigii) powder on quality of ground and cooked goat meat.** A. K. Das*, V. Rajkumar, D. K. Diwvedi, and M. C. Sharma, *Central Institute for Research on Goats, Makhdoom, Farah, India*.

The antioxidant effect of curry leaf powder (CLP) was determined by assessing the formation of lipid peroxides, free fatty acids (FFA) and thiobarbituric acid substances (TBARS) in fresh ground and cooked goat meat patties during refrigerated storage. Results showed that methanolic extract exhibited higher 1, 1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity of 68% at 100 µg than ethyl alcohol, hexane, and chloroform extract, which showed DPPH radical scavenging activity of 62%, 55% and 47%, respectively. pH, water holding capacity and cooking loss per cent were not affected by curry leaf powder when added to fresh ground goat meat. Fresh goat meat with CLP had acceptable odor up to 5 days whereas in control sample it was up to 3 days. Raw goat meat with CLP had significantly lower free fatty acids content than control during 9 days of refrigerated storage. CLP significantly inhibited the rate of lipid peroxides and TBARS formation in fresh ground meat compared to untreated control. CLP in cooked goat meat patties showed significant antioxidant effect as indicated by TBARS values measured by distillation as well as extraction method. CLP did not affect microbial populations in fresh and

cooked goat meat during the storage period. These results show that CLP at concentrations as low as 0.2% is a very effective inhibitor of primary and secondary oxidation products in fresh ground and cooked goat meat patties and has potential as a natural antioxidant in fresh and cooked meat systems. Curry leaf powder seems to have no anti-microbial effect on fresh as well as cooked goat meat patties during storage.

**Key Words:** curry leaves, anitoxidat effect, lipid oxidation, meat quality

**14 The functionality of selected pea and corn starches in bologna sausages as affected by fat and salt contents.** Z. Pietrasik and D. L. Pierce*, *Alberta Agriculture & Rural Development - Food Processing Development Center, Leduc, AB, Canada*.

Traditionally, low cost starches have been used in the formulation of processed meat products to bind water, increase viscosity, and improve texture. Both native corn starches and modified corn starches are commonly used in meat product formulations because their functionality is well documented; they are low cost and readily available on the market. Pea starch is a novel ingredient for which there is limited information regarding its functionality in meat products. Characterizing the functionality of pea starches in meat systems will add value to the largely commodity-based dry pea industry in Canada. The functionality of a native corn starch, a modified corn starch, and two types of native pea starch; air-classified pea starch and wet-extracted pea starch from yellow peas, were examined at 3% inclusion level in a model bologna compared to samples without starch incorporation. The performance of starches was evaluated in a factorial combination of two fat levels (LF, 10% and HF, 25%) and two salt levels (LS, 1.5% and HS, 1.8%). Meat protein level was adjusted to 12% in all formulations. Processing functionality was evaluated by cook loss and moisture retention properties (expressible moisture and purge during storage). Texture Profile Analysis was used to evaluate the textural characteristics of the bologna. Regardless of starch type used, HF bolognas had a lower cook loss and better hydration properties than the LF bologna ($P < 0.01$). HS formulation had a 25.6% lower cook loss ($P < 0.03$) and improved hydration properties compared to the LS formulations. The effect of starch type on hydration properties was dependent on fat level as indicated by starch x fat level interactions ($P < 0.01$). In the LF formulation the addition of all starches significantly ($P < 0.01$) reduced cook loss, however, corn starches were more effective than pea starches. In HF bologna both corn starches significantly ($P < 0.01$) reduced cook loss whereas bolognas with pea starches were not different from the control treatment. Addition of all starches significantly ($P < 0.01$) reduced the amount of purge in vacuum-packaged HF samples after 4 weeks storage whereas the addition of pea starches did not reduce the purge after storage compared to the control in LF samples. Reducing the fat level increased hardness in control bologna samples. The addition of corn starches did not affect bologna hardness in HF formulations and produced a softer texture when added to LF bolognas, while the addition of pea starches resulted in a harder bologna, regardless of fat level. Incorporation of corn starches into the LF bologna resulted in hardness equivalent to the HF control bologna. Springiness and chewiness was not affected by starch addition in either of the HF and LF bologna formulations. The LS bologna formulation displayed lower values for hardness and chewiness than the HS bologna. Salt concentration did not affect the springiness of the bologna. The addition of starches had a greater effect on the LF bologna than the HF bologna. Overall the addition of pea starches

is not beneficial in HF bologna formulations. Pea starch does add value to LF bologna; however, corn starch is more functional. No significant differences were found between modified and native corn starches; nor did the extraction method result in significant differences between the pea starches.

**Key Words:** pea starch, meat, function

**15 Chemical composition, nutritional value, cooking properties, and oxidative stability of meat emulsions formulated with vegetable oils and plant extracts.** R. M. Delles*[1], D. Alvarez[1], Y. L. Xiong[1], M. Castillo[2], and F. Payne[2], [1]*University of Kentucky, Department of Animal and Food Science, Lexington,* [2]*University of Kentucky, Department of Biosystem and Agricultural Engineering, Lexington.*

The consumer demand for healthier foods has led to the development of mono and polyunsaturated fat replacements and antioxidant enriched emulsion-type meats in recent years. The objective of the study was to determine the effect of several functional ingredients on the technological parameters related to pork emulsion stability, as well as on the reduction of caloric values. Emulsions were prepared in duplicate using normal pork backfat (20%), canola oil (20%), and canola/olive oil blend (15%/5%), with two types of plant extracts (non-use; rice bran 2.5%; walnut 2.5%). The weight loss of emulsions after thermal treatment (smoke house), total fluids and fat exuded during cooking, and the moisture, protein, and fat content, the energy (kcal/100 g) level, and lipid oxidation of frankfurters during storage (up to 3 weeks at 4C) were measured. Of all frankfurter formulations, emulsions made with 20% backfat had the greatest protein (14.7%) and moisture (59.6 %) contents. Percent moisture declined upon the addition of walnut extract and rice bran in emulsions where pork backfat (20%) was replaced with canola oil. The addition of walnut extract increased ($P < 0.05$) the energy values up to 303 kcal/100 g in emulsions made with canola oil but not in emulsions with backfat and canola/olive oil blend. The addition of rice bran in emulsions made with 20% backfat resulted in the greatest total exudates after cooking. In general, no difference ($P > 0.05$) in weight loss or fat exudation was observed in emulsions with or without the addition of rice bran or walnut. Lipid oxidation (TBARS) increased slightly from day 0 to day 7 (mg/kg) in all frankfurters, but the TBARS values slowly declined afterward. There was a significant difference ($P < 0.05$) in canola oil and canola oil with rice bran; significances were also observed between plant extracts added to either canola oil or canola/olive oil fat replacement emulsions. The use of these functional ingredients did not significantly affect the emulsion stability and the energy values, producing no significant changes in the oxidation level of final products in comparison with regular frankfurters made with pork fat. Thus, these oil replacements could be used as natural ingredients in healthy meat product preparation.

**16 Evaluation of beef frankfurters manufactured from high and normal pH shoulder clods.** L. G. Garcia, W. N. Osburn*, D. S. Hale, and J. W. Savell, *Texas A&M University, College Station*.

Approximately 2.1% of cows harvested annually in the U.S. produce carcasses that are

considered "dark cutters" which exhibit dark-colored lean and typically have a muscle pH greater than 6.0. The objective of this study was to evaluate the functional properties of beef frankfurters manufactured with varying levels of high and normal pH shoulder clods. Shoulder clods (lean source, IMPS #114) and plates (fat source, IMPS# 121) were obtained from cow carcasses representing two pH categories: 1) normal (pH 5.4 to 5.8) and 2) high (pH ≤ 6.2). Shoulder clods and plates from each category were ground separately through a 1.27 cm plate, reground through a 0.48 cm plate, and samples collected for fat analysis. Appropriate amounts of lean and fat from each pH category were combined with selected ingredients to manufacture six frankfurter batches (~13 kg each) with 10% fat and 30% added water. Frankfurter treatments were: 1) 100% high pH (100H); 2) 75% high pH/25% normal pH (75H/25N); 3) 50% high pH/ 50% normal pH (50H/50N); 4) 25% high pH/75% normal pH (25H/75N); and 5) 100% normal pH (100N), and 6) control (C) (normal pH, 0.5% added sodium tripolyphosphate).
Frankfurter emulsions were stuffed into cellulosic casings (30 mm dia) and linked (86 g/link). Raw emulsion samples were collected to determine emulsion pH, stability, and hydration. Frankfurters were cooked to an internal temperature of 71°C, chilled (4°C), peeled, vacuum packaged (4 links/package) and stored at 4°C until analyzed for cook yield, pH, proximate composition, internal color, microbial growth, lipid oxidation (2-thiobarbituric acid reactive substance, TBARS) and purge at 0, 28, and 56 days of storage. Textural profile analysis (TPA) and trained sensory evaluation was conducted at day 28 of storage. Raw emulsion pH did not differ among treatments. Emulsion stability (total volume of water, solids and fat loss) was highest for C (1.98 mL), followed by 100H (3.37 mL). As the percentage of high pH meat decreased, emulsion stability decreased (100N 9.36 mL). The 25H/75N and 100N treatments exhibited the lowest hydration values (0.71 mL and 0.44 mL water loss, respectively). Cook yields among all treatments ranged from 88 to 91%. At day 28, all treatments exhibited microbial counts of 6.4 log/CFU or greater however, 100H and 75H/25H had the lowest microbial counts (log/CFU 6.4 and 6.7, respectively). Frankfurter internal color became lighter and less red as length of storage increased. Minimal lipid oxidation occurred among all treatments (0.13 to 0.17 mg malonaldehyde/kg sample) by day 56. TPA analysis determined that 100H was harder and less cohesive than other treatments. Descriptive sensory data found no differences among treatments for juiciness, aromatic, basic tastes and mouthfeels but found that frankfurters containing at least 50% high pH meat were harder. Results from this study suggest that frankfurters containing various percentages of high pH meat were similar in emulsion stability, hydration, lipid oxidation, color, sensory and textural attributes compared to a control with added phosphate. However, due to the increase in microbial growth during refrigerated storage, an antimicrobial is necessary to improve shelf life.

**Key Words:** pH, frankfurters, beef

**17 Combining rosemary and green tea extract to offset the negative impact green tea imparts on meat color.** K. L. Robbins*, *Kemin Food Ingredients, Des Moines, IA.*

The shelf life of processed meats is limited by microbial spoilage and oxidative rancidity. Rancidity is responsible for flavor deterioration and color loss, and is also the primary mode of failure for frozen processed meats. Natural plant extracts have been shown to delay oxidative changes as effectively as synthetic phenolic antioxidants, yet they enjoy the advantage of being

labeled as a natural flavor. While green tea extract (GTE) is recognized as having antioxidant properties beneficial to human health, its usefulness as an additive for extending the shelf life of foods is somewhat disputed due to the existence of published literature reports of negative effects on color retention in fresh meat and poultry. The effects of the addition of 0.05% GTE or 0.2% of a mixture of green tea and rosemary extracts (GTR) on the sensory attributes and lipid stability of both raw and cooked ground pork were compared to an untreated control. The cooked ground pork samples were sealed in polyethylene pouches and immersed in a 65°C water bath for 4 hours in order to induce oxidative degradation. Thiobarbituric acid reactive substances (TBARS) were evaluated after the heat treatment. The 0.2% GTR provided a significant ($P$<0.05) improvement in TBARS (0.62 mg/kg) when compared to the GTE and untreated control (TBARS = 1.57 mg/kg and 5.85 mg/kg, respectively). While the sensory panelists found the flavor of both the GTR and GTE acceptable, they judged the GTR sample as having more intense meaty flavor than the GTE sample. As expected, the $a^*$ (redness) value of the raw ground pork patties declined during refrigerated storage over 12 days. Multiple regression analysis revealed that the GTR was more effective ($P$<0.05) in delaying the decline in redness than the GTE and the untreated control, with the difference becoming significant from day 3 onwards. Furthermore, the $a^*$ value of the GTR samples on day 12 were similar to the GTE samples on day 5 and the untreated control on day 6. This study demonstrated that combining rosemary extract with GTE can successfully offset the negative impact which GTE has on fresh meat color.

**Key Words:** green tea, rosemary, shelf life

**18 Characterization of lactate-myoglobin interactions using mass spectrometry.** R. A. Mancini[1], S. P. Suman[2], M. K. R. Konda*[1], R. Ramanathan[1], P. Joseph[2], and C. M. Beach[2], [1]*University of Connecticut, Storrs*, [2]*University of Kentucky, Lexington.*

An increased demand for case-ready meat products has led processors to implement numerous injection-enhancement technologies that add value and lengthen product shelf-life. Lactate is a commonly used ingredient that darkens and stabilizes color in raw and cooked meat products. Research determining the fundamental mechanisms by which lactate influences color stability has not considered a direct effect of lactate on myoglobin. Thus, the objective of this study was to use Matrix Assisted Laser Desorption Ionization–Time of Flight Mass Spectrometry (MALDI-TOF MS) to examine lactate adduction to myoglobin. The overall experiment was replicated three times (n = 3) with duplicate sub-samples per replication. Deoxymyoglobin was prepared by sodium hydrosulfite-mediated reduction of equine heart myoglobin (Mb). Oxymyoglobin (OMb) and carboxymyoglobin (COMb) were prepared by bubbling deoxymyoglobin with atmospheric air or a gas mixture containing 0.4% CO for 40 min, respectively. Residual sodium hydrosulfite was removed by passing the OMb and COMb preparations through PD-10 columns. Equine OMb and COMb (0.15 mM) were incubated with sodium lactate (200 mM) at 4 °C, pH 5.6 in 50 mM sodium citrate buffer for 8 days or at 37 °C, pH 7.4 in 50 mM sodium phosphate buffer for 360 min, simulating typical meat storage and physiological conditions, respectively. Controls consisted of myoglobin plus a volume of deionized water equivalent to that used to deliver lactate treatments. No peaks corresponding to lactate-Mb adducts could be detected in the MALDI-TOF MS spectra of samples incubated up to 360 min at pH 7.4, 37 °C or 8 days at pH

5.6 and 4 °C. These results suggest that lactate′s effect on beef color may not be associated with direct interactions between lactate and Mb, but rather is more indirect and possibly mediated through mitochondrial metabolism, lactate dehydrogenase, and antioxidant proteins/peptides in post-mortem skeletal muscles.

**Key Words:** myoglobin, lactate, mass spectrometry

**19 Lactate-modulated improvement of color stability in ground beef is packaging-specific.** S. P. Suman*[1], R. A. Mancini[2], P. Joseph[1], R. Ramanathan[2], M. K. R. Konda[2], and G. Dady[2], [1]*University of Kentucky, Lexington,* [2]*University of Connecticut, Storrs.*

Lactate is described as a color-stabilizer in fresh beef products, promoting the formation of a dark red pigment and minimizing lipid oxidation. Earlier investigations on lactate's effect on ground beef color stability were undertaken either in vacuum or aerobic packaging and did not address the possible influence of modified atmosphere packaging (MAP) systems. Therefore, our objective was to determine the effects of lactate on surface color stability of ground beef in different MAP systems. Coarse ground beef (85% lean) was mixed either with 2.5% potassium lactate or without lactate and was hand-formed into 100-g patties, which were packaged in high-oxygen MAP (HI-OX; 80% $O_2$ + 20% $CO_2$ ), low-oxygen MAP (LO-OX; 0.4% CO + 19.6% $CO_2$ + 80% $N_2$ ), vacuum (VP),or aerobic over-wrap packaging (PVC), and stored for 0, 48, or 96 hours at 1 °C in the dark. Patties were removed from packaging, and surface color (CIE *L**, *a**, *b**) was measured immediately using a HunterLab MiniScan XE Plus spectrophotometer. Overall, lactate-patties demonstrated lower ($P < 0.05$) *L** values (were darker) than control samples. In PVC, HI-OX, and VP, surface *a** values (redness) were greater ($P < 0.05$) for lactate-patties than the controls. However, lactate's influence on *a** values was not evident ($P > 0.05$) in LO-OX, possibly due to the color-stabilizing effect of CO on beef. These findings indicated that the color-stabilizing effect of lactate is pronounced in PVC, HI-OX, and VP. Irrespective of lactate-treatment, patties stored in LO-OX exhibited greatest ($P < 0.05$) surface redness. The results of the present study suggested that the color-stabilizing effect of potassium lactate on ground beef is packaging-specific. Prolonging the color shelf-life of beef through optimal combination of MAP and ingredient technology is a logical strategy to minimize the revenue loss to the US beef industry.

**Key Words:** lactate, modified atmosphere packaging, ground beef

**20 Effects of lactate-enhancement on surface reflectance and absorbance properties of beef longissimus steaks.** R. Ramanathan*[1], R. A. Mancini[1], B. M. Naveena[2], and M. K .R. Konda[1], [1]*University of Connecticut, Storrs,* [2]*National Research Centre on Meat, Hyderabad, Andhra Pradesh, India.*

Estimating myoglobin redox forms on the surface of meat relies upon reflectance at isobestic wavelengths. K/S ratios are input into the appropriate formulas for estimating myoglobin forms specified in the Guidelines for Meat Color Evaluation (AMSA, 1991). However, creating reference standards for 100% of each myoglobin form as well as equation-dependent calculations

depends upon the reflectance properties of meat, which can be influenced by salt addition. Thus, the objective of our study was to assess the effects of lactate-enhancement on the surface reflectance and absorbance properties of beef longissimus steaks.
Using a completely randomized block design, seven USDA strip loins were divided into four sections. One of the four units per loin was assigned to day 0 color measurements in order to characterize non-enhanced beef. The other three sections were assigned to one of three treatments (non-enhanced, water-enhanced, and 3% lactate), vacuum packaged, and stored for 5 days at 4 °C. On either day 0 or day 5 of storage, loin units were cut into steaks that were used to prepare 100% of Deoxy-, Oxy-, Met- and Carboxymyoglobin. Surface color was analyzed on steaks from each myoglobin form using a HunterLab Miniscan Plus Spectrocolorimeter. CIE L*, a*, b*, chroma, hue angle, overall reflectance, and overall absorbance values were used to characterize steak surface color. Type-3 tests of fixed effects for injection-enhancement treatments were performed using a one-way ANOVA in the MIXED procedure of SAS.
Lactate-enhanced steaks had the least overall surface reflectance and the darkest surface color (lower L*; $P < 0.05$). In agreement with reflectance data, lactate-enhancement increased ($P < 0.05$) absorbance compared with both non-enhanced and water-enhanced steaks. Although lactate-enhancement changed the magnitude of overall % reflectance, 525 nm tended to remain isobestic for all four myoglobin forms. In addition, approximately 474, 572, and 610 nm remained isobestic for DMb, MMb, and OMb, respectively. Both lactate-enhanced and non-enhanced steaks had wavelength absorbance maxima at approximately 500, 540, 560, and 580 nm for 100% MMb, COMb, DMb, and OMb.
Enhancing beef loins with lactate will decrease the magnitude of overall surface reflectance compared with non-enhanced and water-enhanced steaks. This can result in a darker color via increased absorbance of light. Although lactate-enhancement may not horizontally shift isobestic wavelengths for 100% myoglobin forms, changes in vertical magnitude of surface reflectance will influence K/S ratios at isobestic wavelengths. Thus, when using AMSA equations (1991) to estimate myoglobin on the surface of lactate-enhanced beef, reference standards for 100% DMb, OMb, and MMb should be derived specifically from lactate-enhanced beef.

**Key Words:** lactate, surface reflectance, beef color

**21 Differential susceptibility of color-stable and color-labile beef muscles to premature browning.** S. P. Suman*[1], R. A. Mancini[2], R. Ramanathan[2], and M. K. R. Konda[2], [1]*University of Kentucky, Lexington*, [2]*University of Connecticut, Storrs*.

Beef color-stable (*Longissimus lumborum*; LL) and color-labile (*Psoas major*; PM) muscles exhibit striking differences in color stability attributes as well as biochemistry. Previous research indicated that aerobically stored ground beef patties from LL demonstrated a greater tendency to undergo premature browning (PMB) than PM patties. However, limited information is available on the tendency of whole-muscle steaks from these two muscles to demonstrate PMB, especially during storage under different modified atmosphere packaging (MAP) systems. Therefore, our objective was to determine the impact of different MAP systems on the susceptibility of steaks from beef color-stable and color-labile muscles to exhibit PMB. Muscles (LL and PM) from sixteen (n = 16) USDA select carcasses were obtained from a local packing plant, and four 1.92-cm steaks were sliced from each muscle. Three steaks were packaged individually in vacuum

(VP), high-oxygen MAP (HI-OX; 80% $O_2$ + 20% $CO_2$ ), or low-oxygen MAP (LO-OX; 0.4% CO + 19.6% $CO_2$ + 80% $N_2$ ), and stored at 1 °C for 9 days in darkness. The fourth steak was not packaged, but was allowed to bloom for 60 minutes at 1 °C and was utilized for day 0 color analyses. At the conclusion of storage, steaks were cooked to an internal endpoint temperature of 66 °C, at which PMB is reported to happen. Cooked steaks were immediately cooled in slushed ice for five minutes, sliced parallel to the grilled surface, and internal red color (*a** value) was analyzed. On day 0, interiors of cooked LL steaks were more ($P < 0.05$) red (greater *a** values) than PM samples. After storage, PM steaks in VP and LO-OX exhibited lower ($P < 0.05$) *a** values than the LL steaks, whereas no differences ($P > 0.05$) existed between *a** values of LL and PM steaks in HI-OX. These results suggested that color-labile beef steaks are more prone to PMB than color-stable steaks when packaged in VP and LO-OX, but not in HI-OX. The interiors of PM steaks in VP, HI-OX, and LO-OX were less ($P < 0.05$) red than day 0 steaks, whereas LL steaks exhibited no loss of interior cooked redness during storage in VP and LO-OX. Overall, LL and PM steaks packaged in VP and LO-OX had greater ($P < 0.05$) *a** values than their counterparts in HI-OX, which demonstrated the least *a** values. Our findings indicated that packaging in HI-OX will predispose beef color-stable as well as color-labile muscles to PMB. Conversely, VP and LO-OX were more advantageous in regard to minimizing PMB compared with HI-OX packaging. Further research is necessary for developing muscle-specific packaging strategies to prevent PMB in whole-muscle steaks.

**Key Words:** premature browning, *Longissimus lumborum*, *Psoas major*

**22 Evaluation of instrumental color properties in beef steaks coated with trisodium phosphate incorporated into a gelatin-coating system prior to packaging.** F. W. Pohlman, A. H. Brown Jr., P. N. Dias-Morse*, L. M McKenzie, L. N. Mehall, and T. N. Rojas, *University of Arkansas, Fayetteville*.

Many studies have confirmed that antimicrobial decontamination techniques are effective in minimizing or eliminating pathogenic bacteria in meat products. However, these techniques may cause undesired effects on meat color and lead to major impact on consumer's purchase decision. According to Pohlman et al. (2002), the use of 10% trisodium phosphate in ground beef prior to grinding was effective in improving microbial properties and sensory overall color. Jimenez-Villarreal et al. (2003) re-confirmed that use of 10 % trisodium phosphate may improve the color characteristics of ground beef. The incorporation of antimicrobial substances into edible coating systems is a rapidly growing field which may offer improved microbial safety along with improved sensorial properties of the product (Vermeiren et al., 2002). Therefore, trisodium phosphate in such coating system may grant enhanced microbial product safety without causing deleterious effects on meat color. However, detailed information about the performance of trisodium phospahte in a gelatin coating system on meat quality characteristics is scarcely available. Hence, our objective is to assess the effect of trisodium phosphate incorporated into a gelatin-coating system, prior to packaging, on beef steak instrumental color characteristics. Inoculated steaks from strip loins (IMPS=180; Escherichia coli and Salmonella typhimurium $10^7$ log CFU) were dipped in gelatin (GEL), gelatin with 10 % (GEL+10TSP) or 5% (GEL+ 5TSP) trisodium phosphate or 10 % trisodium phosphate (10TSP) for 1 min. Next, treated steaks, untreated-inoculated control (INCON) and untreated non-inoculated control (CON) steaks were

packaged and displayed under simulated retail conditions (4°C) until used in the study. Instrumental color was measured on days 0, 1, 2, 3, and 7 of simulated display using a Hunter-Lab MiniScan XE Spectrocolorimeter (illuminant A/10° observer). Samples were evaluated for CIE lightness (L*), redness (a*), and yellowness (b*), hue angle, saturation index and reflectance ratio. All the treatments had similar (P>0.05) L*, a*, b* and saturation index compared to CON on days 1 and 7. However, GEL+5TSP maintained a similar (P>0.05) L*, a*, b*, hue angle, saturation index and reflectance ratio values to CON on days 1 through 7 of display. These results indicated that 5 % TSP incorporated into a gelatin coating will be more advantageous compared to direct TSP application, gelatin coating without TSP or gelatin coating with 10% TSP in improving and maintaining instrumental color properties of beef steaks for prolonged periods.

**Key Words:** beef steaks, antimicrobial coating, instrumental color

**23 Comparative color shelf life of ground beef packaged with carbon monoxide against that of traditional vacuum packaged ground beef.** J. Y. Jeong* and J. R. Claus, *University of Wisconsin, Madison.*

The public often is mislead by a direct comparison made between the color stability of carbon monoxide packaged (anaerobic, CO-MAP) and an $O_2$ permeable packaged (aerobic) ground beef. The microbiological shelf life of anaerobically-packaged ground beef is far superior to aerobically-packaged ground beef. This study provided a direct color shelf life comparison of two anaerobic package systems (vacuum package, CO-MAP) when left intact or after opening the packages. Fresh, boneless, vacuum-packaged beef chuck trim (85% lean trim, 3-day postmortem) from Holstein steers was coarsely ground (0.95-cm plate), mixed (3 min), and reground (0.32-cm plate). Ground beef was either vacuum-packaged or CO-MAP (0.4 CO, 30% $CO_2$, 69.6% $N_2$). After these packages were stored (48 h at 2-3°C) under continuous fluorescent light (1076 lux, 40W Cool White Deluxe light), one vacuum package and CO-MAP package were fully opened, exposed to air for 40 min before starting the color determinations, and then overwrapped with polyvinyl chloride (PVC) film. One vacuum and CO-MAP package were left intact. Packages were continuously displayed for up to 7 days (2-3°C; (Experiment 1). Intact packages were further displayed for 14, 21, 28, or 35 days (Experiment 2). At 35 days of display, the intact packages of ground beef were opened, overwrapped with PVC film, and then displayed for 1 or 3 days (2-3°C; Experiment 3). CIE color and spectrophotometric reflectance were periodically measured at designated display days. All experiments were replicated three times. Data within each of the three experiments were analyzed separately using the PROC MIXED Model procedure of SAS. After the vacuum and CO-MAP packages were opened and overwrapped in PVC, the red color decreased (CIE a* day 0: 20.67, 26.12, day 7: 8.44, 8.96; vacuum and CO-MAP package, respectively) with display time in the ground beef from both package types (Experiment 1). The rate of color loss in opened vacuum-packaged ground beef was faster than in the opened CO-MAP-packaged product. However, there was no difference (P > 0.05) in CIE a* values between vacuum-packaged and CO-MAP-packaged ground beef at 7 days after opening. In the case of intact packages, continuous exposure of ground beef to carbon monoxide in CO-MAP packaging generally increased redness whereas the color of vacuum-packaged ground beef remained relatively stable throughout 35 days of display. Intact CO-MAP

packaged ground beef always had more red than intact vacuum-packaged ground beef (Experiment 2). Upon opening the packages at 35 days of storage (Experiment 3), the color of both packages deteriorated with display time. However, opening the vacuum-packaged ground beef compared to CO-MAP-packaged product showed a higher rate of color deterioration. When CO-packaged product is opened or the seal integrity has failed, this color deterioration would provide consumers with a visual indicator of freshness.

**Key Words:** color, carbon monoxide packaging, ground beef

**24 Color stability associated with exposure to carbon monoxide and conversion of metmyoglobin to carboxymyoglobin in carbon monoxide modified atmosphere packaged (CO-MAP) ground beef.** J. Y. Jeong* and J. R. Claus, *University of Wisconsin, Madison*.

This study investigated the relationship between length of exposure to carbon monoxide and the rate of loss of carboxymyoglobin color in CO-MAP packaging (Experiment 1), and the ability of carbon monoxide to cause color reversion of metmyoglobin (MMb) to carboxymyoglobin (Experiment 2). Fresh, boneless, vacuum-packaged beef chuck trim (85% lean trim, 3-day postmortem) from Holstein steers was used. Beef was ground (0.95-cm, 0.32-cm plates). Ground beef (Experiment 1) was vacuum-packaged and the package was immediately inflated with a CO-MAP gas mixture (0.4% CO, 30% $CO_2$, 69.6% $N_2$; gas to meat, 1.5 to 1) and stored at 2-3°C in the light. Packages were displayed (1, 2, 4, 6 days) before being opened, PVC-overwrapped and redisplayed (0, 24, 48, 72 h). To establish naturally developed or low-oxygen induced brown color (Experiment 2), ground beef initially was overwrapped in PVC film (MMb-1) for 4 days or packaged in 0.1% $O_2$ (MMb-2) for 2 days (2-3°C). One set (MMb-1; MMb-2, opened and overwrapped in PVC) was continuously displayed (2-3°C) under fluorescent light (1076 lux, 40W Cool White Deluxe light), and a second set was repackaged in CO-MAP and stored up to 7 days in the dark (2-3°C). CIE L*a*b* and spectrophotometric reflectance were measured on 0, 1, 3, 5, or 7 days. Data within each of the two experiments (three replications) were analyzed separately using the PROC MIXED procedure of SAS. In experiment 1, the mean CIE a* value for ground beef became more red ($P < 0.05$) with each exposure time (intact CO-MAP; day 0, a* 19.3; day 6, a* 22.5). Mean reflectance ratio (%R610nm/%R525nm, indicator of redness) was highest ($P < 0.05$) on day 6 during the intact CO-MAP display. However, upon opening the CO-MAP, the red color of ground beef deteriorated relatively rapidly. Loss of this color change would warn consumers of a compromised package (leaker). In experiment 2, the naturally developed and low-oxygen-induced brown ground beef had a similar initial color (CIE a*, 12.1; chroma, 14.4; %R610nm/%R525nm, 1.6). However, after this beef was CO-MAP, the color changed from brown to red (day 7: CIE a* value, 27.4; chroma, 28.6; and the ratio of %R610nm/%R525nm, 2.7). Therefore, carbon monoxide had the ability to cause a color reversion of metmyoglobin to carboxymyoglobin in ground beef, regardless of how the initial brown color was formed (MMb-1 or MMb-2). This color change was relatively faster in MMb-2 ground beef compared to MMb-1. Although this color reversion suggests the potential for the industry to misuse carbon monoxide to rejuvenate the color of spoiled meat, the odor would remain as a clear inhibitor of such an ill-advised practice. On the other hand, in the case of pigment oxidation that can occur in fresh ground beef associated simply with low partial pressures of oxygen, exposing such meat to carbon monoxide would be beneficial.

**Key Words:** color stability, color conversion, CO-MAP packaging

**25 Evaluation of overwrapped beef strip steaks packaged in a mother-bag case-ready system utilizing Tewari Zero-OxTech™ System.** J. M. Behrends* and C. M. Leick, *Mississippi State University, Mississippi State.*

The objective of this study was to evaluate color stability of case-ready, overwrapped beef stored in mother bags with Tewari Zero-OxTech™ scavengers for up to four weeks. The Tewari Zero-OxTech™ System utilizes half-life theory to absorb residual oxygen in mother bags and extend shelf-life of case-ready beef. Beef strip loin steaks (n=32) were overwrapped, stored in mother bags with Tewari Zero-OxTech™ scavengers for 1, 2, 3, or 4 weeks. Each mother bag (OTR 2 cc/sq m/ 24H/23C/75%RH) was evacuated of oxygen and filled with a mixture of 71.6% N, 28% $CO_2$, and 0.4% CO. In addition, optimized Tewari Zero-OxTech™ scavengers were added to the bag to capture residual oxygen from the bag based on the half-life. The steaks were removed from the mother bag during the assigned week and then placed on retail display. Steaks were evaluated on d0, d3, d5, and d7 of display for subjective color (beef color and discoloration) and objective color (L*, a*, b*, and a*/b* ratio). Beef color scores decreased ($P<0.05$) with increasing display days after 2 and 3 weeks of storage. Discoloration scores increased over the 7d display period, but were similar ($P>0.05$) across weeks of storage on d0, d5, and d7 of display. L* values decreased ($P<0.05$) with increasing display time. Overall b* values were lower after 4 weeks of storage ($P<0.05$) compared to 1, 2, or 3 weeks of storage, but were not affected by display days. The a* values and a*/b* ratios at d0 and d3 of display were similar across weeks of storage, but were decreased at d5 and d7 of display with increasing weeks of storage ($P<0.05$). All steaks exhibited acceptable color shelf-life from d0 to d3, which is the typical number of storage days in a retail display case. This study indicated that the Tewari Zero-OxTech™ System extended color shelf-life of beef strip loin steaks to 4 weeks in mother bags with an additional 3 d minimum retail display.

**Key Words:** case-ready beef, motherbags, oxygen scavengers

**26 High oxygen packaging system negatively affects color stability and sensory attributes of beef cuts.** Y. H. Kim*, S. M. Lonergan, and E. Huff-Lonergan, *Iowa State University, Ames.*

Modified atmosphere packaging (MAP) systems with a high oxygen (80%) level are widely used in retail meat markets because the bright red color of meat in this packaging system attracts consumers. However, high oxygen levels are likely to increase the incidence of oxidative changes in the meat, thus negatively affecting meat quality characteristics. Further, it may cause more quality problems for some beef round muscles, which have traditionally been underutilized because of commonly-noted tenderness and discoloration defects. The objectives of this study were to determine the effect of different packaging systems [high oxygen MAP (HiOx-MAP) and vacuum (VAC)] on color stability, lipid oxidation, and sensory attributes of beef round cuts. Ten market weight beef cattle (A-maturity) were slaughtered at the Iowa State University Meat

Laboratory. The longissimus lumborum (LL; control muscle), semimembranosus (SM), and adductor (AD) muscles were removed from each carcass at 24 hours after slaughter. Steaks (2.54-cm thick) were cut perpendicular to the long axis of each muscle and randomly assigned to either HiOx-MAP (80% O2, 20% CO2) or VAC for packaging. Steaks were displayed for 9 days at 1°C under 2150 lux of fluorescent light. Surface color (Hunter), pH, thiobarbituric acid reactive substance (TBARS) values, star probe, and sensory analysis were measured on steaks at the begining and at the end of display. Type-3 tests of fixed effects for muscle, packaging, display time, and their interactions were performed using the Mixed procedure of SAS. Least square means were separated ($P < 0.05$) by using the diff option. HiOx-MAP-packaged beef steaks had significantly lower tenderness and juiciness scores compared to steaks in VAC. However, star probe did not differ between packaging treatments. The steaks from SM and AD had lower ($P < 0.05$) tenderness scores and higher chewiness compared to LL. HiOx-MAP significantly increased off-flavor development. HiOx-MAP packaged beef steaks had an increase ($P < 0.05$) in lipid oxidation during display. The AD in HiOx-MAP had the greatest increase of lipid oxidation (0.14 to 1.57 mg malonaldehyde/kg meat at d1 and 9 respectively) during display followed by SM (0.12 to 1.17) and LL (0.14 to 0.9) suggesting that these beef round muscles are more susceptible to oxidation than LL. In contrast, the steaks packaged in VAC did not develop lipid oxidation (0.09 mg malonaldehyde/kg meat) during display time. The surface redness values (a* value) of steaks packaged in HiOx-MAP rapidly decreased during display, and AD had the greatest decrease ($P < 0.05$) in surface redness (indicating more myoglobin oxidation) followed by SM and LL. However, VAC steaks had no significant change in redness during display. These data suggest that HiOx-MAP can create more oxidative conditions, which negatively affects myoglobin and lipid stability, meat, tenderness, juiciness and flavor. Further, the results support the hypothesis that conditions that promote oxidation are detrimental to improvement in tenderness with postmortem aging. MAP systems with lower oxygen mixture (low oxygen MAP or carbon monoxide-MAP) or incorporation of antioxidants through injection enhancement to meat in HiOx-MAP are recommended to minimize oxidation-induced quality deteriorations of beef round muscles.

**Key Words:** MAP, beef quality, oxidation

**28 The survivability, growth and heat susceptibility of *E. coli* 0157:H7 in enhanced beef brine solutions containing potassium lactate and lactic acid producing bacteria.** A. R. Rosenberg*[1], J. C. Brooks[1], G. H. Loneragan[2], M. F. Miller[1], and M. M. Brashears[1], [1]*Texas Tech University, Lubbock,* [2]*West Texas A&M University, Canyon.*

Meat enhancement is used to increase consumer satisfaction through improved palatability and uniformity. Brine solutions that are re-covered or reused during the processing of enhanced meat cuts have a high risk of cross contamination. The objectives of the present study were to determine the effect of potassium lactate and lactic acid bacteria on the survivability and heat susceptibility of *E. coli* O157:H7 in brine solutions used to enhance beef products and to determine the effect of these interventions on consumer sensory scores and shelf life characteristics. To characterize safety, beef strip loins were enhanced with brine solutions (0.3% sodium chloride and 0.35% phosphate at 10% pump level) inoculated with high or low levels of E. coli O157:H7 and one of the following interventions: 0, 1.5, 2.5% potassium lactate or lactic

acid bacteria (LAB 107 CFU/ml). Treated subprimals were fabricated into steaks and randomly allotted to one of the following internal endpoint temperatures: 0 (not cooked), 50, 55, 60, 65, 70 and 75°C. Once endpoint temperature was reached, the interior of each steak was sampled and *E. coli* O157:H7 was enumerated (high level) or detected (low level). To characterize palatability and shelf life, beef strip loin subprimals were enhanced with brine solutions containing previously mentioned interventions plus a non-enhanced control. Consumer panelists evaluated palatability at 14 d postmortem and lean color on days 1, 3, and 7 of display (after a 14 d postmortem dark storage period). Display steaks were packaged in high-oxygen (80% O2 / 20%CO2) or low-oxygen (0.4%CO/30%CO2/69.6%N2) modified atmosphere packages. Data analysis showed no significant interactions between intervention treatment and steak temperature endpoints, indicating *E. coli* O157:H7 from treated brine solutions were not more susceptible to heat during cooking. Results also indicate the transference of pathogens into meat products was low for all interventions, regardless of inoculation level. Internal steak temperature (especially 70 and 75°C) remains the most effective way to reduce pathogen levels in steaks enhanced with inoculated brine solutions. Steaks packaged in high-oxygen MAP and enhanced with a brine solution containing 1.5 or 2.5% potassium lactate maintained more desirable lean color scores throughout display and were more likely to be purchased by consumers than steaks enhanced with other treatments. Finally, the presence of potassium lactate (1.5 and 2.5%) and lactic acid producing bacteria had no detrimental impact on consumer palatability, while enhanced steaks were more desirable than non-enhanced controls.

**Key Words:** beef, enhancement, *E.coli*

**29 Growth patterns of *Escherichia coli* O157:H7 and *Salmonella* in temperature-abused ground beef packaged in modified atmosphere packaging systems and traditional systems.** A. M. Laury*, M. A. Alvarado, J. C. Brooks, and M. M. Brashears, *Texas Tech University, Lubbock.*

Ground beef products may be subjected to temperature abuse before or after purchase by consumers, therefore, the objectives of this study were to determine if *E. coli* O157:H7 and *Salmonella* growth was inhibited under temperature abuse conditions in various MAP packaging environments compared to traditional PVC overwrap packaging. To evaluate this objective, a cocktail of *E .coli* O157:H7 or *Salmonella* was used to inoculate ground beef patties (80% lean, 20% fat) at a 1 x 103 cfu/g inoculation level in four replications. The packaging types were: vacuum bags (VAC), chub (overwrap) and three different modified atmosphere packaging (MAP) trays with a high oxygen blend (80%O2/20% CO2) (HO), a low oxygen carbon monoxide MAP (0.4% CO/35% CO2/64.6% N2) (CO), and low oxygen MAP (35%CO2/65% N2) (WOCO). Each tray or bag contained two patties. One package from each packaging type was processed after 24 hours of refrigeration in the dark. On day 5 of dark storage at 4°C, the inoculated ground beef chubs were unpackaged and placed onto plastic trays with overwrap film and were placed in the retail display case (37 F) for 24 hours. On day 6 the packages were randomly placed in three groups for temperature abuse (37 F walk in cooler in the dark, 8 hours at 70F, and 95F for 4 hours). After the temperature abuse, the packages were placed back in the dark 37F walk in cooler. One package from each combination was taken on day 9, 11, 14, and 24 days. *Salmonella* samples were plated onto Rambach agar and *E. coli* O157:H7 samples on

MacConkey agar with CT. Our results demonstrate higher numbers of *E. coli* O157:H7 in PVC compared to other packaging types under all abuse condition; and no significant difference between VAC, HO, CO and WOCO. A temperature of storage and a day of sampling effect were observed. Packages stored at 38 F had significantly lower *E. coli* O157:H7 compared to those at 95 F, but both were statistically the same as packages stored at 70 F. Additionally, ground beef analyzed on days 6 and 14 contained significantly less *E. coli* O157:H7 than days 9 and 11. *Salmonella* recovery was not significantly different in the packaging type nor the storage temperature. However, *Salmonella* concentrations were higher on days 6 and 9, regardless of storage temperature and packaging type. Packaging type by day interaction was highly significant but all other interactions were not significant. When the data is evaluated to determine the simple main effects within the study packaging type PVC was significantly different amongst sampling days and on day 11 and 14 of storage there were significant difference amongst packaging types. Overall, it was evident that packaging other than overwrap has a positive impact on controlling the growth of *E. coli* O157:H7. Samples packaged under these conditions had significantly less *E. coli* O157:H7 growth during temperature abuse and under no abuse conditions. These data suggest packaging types may result in a safer ground beef supply with respect to *E. coli* O157:H7 growth in the product.

**Key Words:** modified atmosphere packaging, temperature abuse, *Escherichia coli*

**30 *Escherichia coli* O157:H7 attachment and survival on stainless steel as affected by levels of initial environmental hydration and sanitizers.** J. M. Adler*, I. Geornaras, K. E. Belk, G. C. Smith, and J. N. Sofos, *Colorado State University, Fort Collins*.

Conditions of the processing environment may affect attachment and biofilm formation by *Escherichia coli* O157:H7 on stainless steel and its susceptibility to sanitizers, thus, affecting the potential for cross contamination. This two part study examined the effect of processing environmental conditions on the attachment and growth of *E. coli* O157:H7 on stainless steel and the efficacy of sanitizers against pathogen biofilms. Stainless steel coupons (2×5×0.1 cm) were inoculated (approximately 3 log CFU/cm$^2$) with *E. coli* O157:H7 (diluted in sterile distilled water; 5 strains) either by applying the inoculum directly onto the surface and allowing to dry (10 min), or submerging the coupons in the inoculum suspension. Inoculated coupons were incubated in 10-fold diluted tryptic soy broth (dTSB; 15°C; 4 days) either statically or with agitation (60 rpm) to simulate a fluid flow. At each sampling interval (0, 0.25, 0.5, 1, 2, 4 days), loosely and firmly attached cells were removed by vortexing at 1000 then 3500 rpm, respectively, and each type was enumerated on tryptic soy agar (TSA). The total attached bacterial population was determined as the sum of cell counts (CFU/cm$^2$) from each vortexing. Strength of attachment (Sr) was calculated as log (total attached) – log (loosely attached). For the second study, 4-day old biofilms, prepared by submerging coupons in inoculum suspension and then incubating (35°C, 4 days) in dTSB or unsterile beef grinder washings (BGW), were dried (30 min) or kept hydrated and subsequently exposed (1, 10 min) to peroxyacetic acid/octanoic acid mixture (PAOA, 2600 ppm), quaternary ammonium compound (QUAT, 400 ppm) or sodium hydroxide (SH, 200 ppm). Rifampicin-resistant *E. coli* O157:H7 was used in order to selectively distinguish the inoculum from natural flora in BGW. Total bacterial and *E. coli* O157:H7 populations were enumerated on TSA and TSA+rifampicin (100 μg/ml), respectively.

Both experiments were replicated twice with three samples analyzed per replicate. A full factorial ANOVA with interactions was analyzed using PROC MIXED in SAS for each experiment. Cells that were allowed to dry on coupons exhibited a higher ($P$<0.05) initial (day-0) Sr than those kept hydrated (0.18 and 0.04, respectively); however, once the biofilms were rehydrated, this difference disappeared. Sr was not affected by a flow of fluid and increased ($P$<0.05) as *E. coli* O157:H7 populations reached maximum attachment levels (≥6.7 log CFU/cm$^2$). In the second study, pathogen counts were reduced by 1.2 log CFU/cm$^2$ when surfaces were dried for 30 min prior to sanitizer treatment. At 1 min of exposure, only PAOA lowered pathogen populations to the detection limit (0.6 log CFU/cm$^2$). Presence of natural flora in BGW allowed a 0.7 log CFU/cm$^2$ increased destruction of the pathogen by sanitizers. Drying of stainless steel decreases viable attached pathogen populations available for product cross contamination. Even though cells in a dried biofilm are more firmly attached onto stainless steel, they are more susceptible to sanitizers than cells in wet biofilms. Peroxyacetic acid/octanoic acid may be preferred over sodium hypochlorite and quaternary ammonium compound for the inactivation of *E. coli* O157:H7 on stainless steel surfaces.

**Key Words:** *Escherichia coli* O157:H7, biofilms, sanitizers

**31 Validation of *E. coli* O157:H7 intervention strategies for multi-needle injected whole-muscle, non-intact beef.** A. Ponrajan*, M. A. Harrison, T. D. Pringle, J. R. Segers, B. K. Lowe, R. O. McKeith, R. M. Pitzer, and A. M. Stelzleni, *University of Georgia, Meat Science and Technology Center, Athens.*

The objective of this study was twofold: 1) to study the effects of two antimicrobials, MOstatin™ and IONAL® (World Technology Ingredients, Inc, Jefferson, GA), on psychrotropic organisms in enhanced top rounds IMPS 169A and top sirloin IMPS 184B (FPL Foods LLC, Augusta, GA) from cull cows, 2) to validate the use of these antimicrobials against *E. coli* O157:H7 for multi-needle injected top rounds from cull cows. Whole muscles were procured 3 d after slaughter, and injected on d 4 to achieve 10% pickup with 0.5% NaCl and 0.4% sodium tripolyphosphate (CNT) plus 2% MOstatin™ (MO) or 1% IONAL® (IN) in the final product. Ten muscles were used for each treatment x muscle combination. After injection, muscles were vacuum sealed and rested at 0±1°C for 10 d. After 10 d, 2.5cm steaks were fabricated into simulated retail packages (PVC overwrap) and stored under luminescence at 4±1°C for 21 d. A 25 cm$^2$ sample was taken from the top surface of each steak on d 1, 7, 14 and 21 and enumerated for psychrotropic organisms (PSY). For the *E. coli* study, 10 top rounds were used for each treatment. The muscles were surface inoculated with ampicillin resistant, green fluorescent pigment expressing *E. coli* O157:H7 (6.40 log CFU/cm$^2$). After injection, muscles were vacuum sealed and rested at 4±1°C for 10 d. After 10 d, the muscles were cut in half. One half was sampled raw and other half was cooked to a core temperature of 60°C and held at 60°C for 12 minutes following Appendix A (USDA) before sampling. A meat block with a 25 cm$^2$ surface area was aseptically excised from the center of the whole muscle sample, sliced in 1/3 increments (top, middle and bottom) and each third was enumerated and enriched for *E. coli* O157:H7 for translocation effects.
For PSY, there was significant treatment x time interaction for both the muscles (P<0.05). For top rounds, there was no significant difference for PSY between the treatments on d 1 (P>0.05);

however, with the increase in time (d 7, 14, 21) CNT had a higher outgrowth of PSY compared to IN and MO ($P<0.05$). For top sirloins, there was a significant treatment x time interaction with CNT having higher PSY counts compared to IN and MO on all days ($P<0.05$). For the raw samples of the E. coli study, in the middle and bottom thirds, there was a significant difference between CNT and IN or CNT and MO treatments ($P<0.05$), but no significant difference between IN and MO treatments ($P>0.05$). In the top third, there was a significant difference between CNT and IN treatments ($P<0.05$), but no significant difference between CNT and MO or IN and MO treatments ($P>0.05$). For all the treatments, there was a significant difference between the top and middle thirds ($P<0.05$). There was also a significant difference between the top and bottom thirds ($P<0.05$), but no significant difference between middle and bottom thirds ($P>0.05$). In the case of the cooked samples, no E. coli was detected. The inclusion of MOstatin™ and IONAL® in enhanced beef products controls psychrotropic organisms and may be an effective *E.coli* O157:H7 hurdle strategy.

**Key Words:** beef, enhancement, *E.coli*

**32 Control of *Listeria monocytogenes* on commercial frankfurters prepared with and without potassium lactate and sodium diacetate and surface treated with lauric arginate using the Sprayed Lethality in Container (SLIC®) delivery method.** S. G. Campano[2], A. C. S. Porto-Fett[1], J. L. Smith[3], A. Oser[3], B. Shoyer[1], J. E. Call[1], and J. B. Luchansky*[1], [1]*U.S. Department of Agriculture, ARS, Wyndmoor, PA*, [2]*Hawkins, Inc., Minneapolis, MN*, [3]*Oser Technologies, LLC, Blacksville, WV*.

The viability of *Listeria monocytogenes* was monitored on commercially-produced frankfurters that were formulated with no, low, or high levels of potassium lactate and sodium diacetate (UltraLac KL6810; low = 0.68% lactate and 0.097% diacetate and high = 1.36% lactate and 0.19% diacetate), and then treated with 22 or 44 ppm of a solution of lauric arginate (LAE; Ethyl-N-dodecanoyl-L-arginate hydrochloride; CytoGuard LA). Frankfurters were removed aseptically from the original package, re-packaged (8 links per bag; 454 grams) into nylon-polyethylene bags, and then surface inoculated with 2 ml of a five-strain mixture of *L. monocytogenes* to achieve a target level of ca. 3.4 log CFU/package. Each package was then massaged by hand for ca. 20 seconds to distribute the inoculum, and then 4 ml of LAE was delivered into each package using the Sprayed Lethality in Container (SLIC®) delivery method. The packages were vacuum-sealed and stored at 4°C for up to 120 days. The pathogen was recovered from frankfurters using the USDA/ARS package rinse method. For each of two trials, three packages were sampled at each sampling interval. In the absence of any antimicrobials, pathogen numbers remained relatively constant for about 30 days, but then increased to ca. 8.4 log CFU/package over 120 days. Regardless of whether or not lactate and diacetate were included in the formulation, when treated with 22 or 44 ppm of LAE, numbers decreased from ca. 3.4 log CFU/package to ca. 1.5 log CFU/package within 2 h. However, after 30 days, for frankfurters without added lactate and diacetate that were subsequently treated with 22 or 44 ppm of LAE, pathogen numbers increased from ca. 1.5 log CFU/package to ca. 7.3 and 6.7 log CFU/package, respectively, at the end of shelf-life. Of note, when frankfurters were formulated with either low or high levels of lactate and diacetate and surface treated via SLIC® with 22 or 44 ppm of LAE, pathogen numbers decreased by ca. 2.0 log CFU/package within 2 h and remained

relatively unchanged over the 120 days of refrigerated shelf life. The use of lactate and diacetate alone prevented the pathogen from growing during shelf life, but did not generate an initial lethality. These data confirm that LAE provides an initial lethality, and that in combination with lactate and diacetate as an ingredient to the batter, will inhibit growth of the pathogen throughout shelf life. As such, manufacturers may consider this strategy to achieve alternative 1 status for ensuring the safety of RTE meat and poultry products relative to a post-process intervention for *L. monocytogenes*.

**Key Words:** *Listeria monocytogenes*, SLIC®, antimicrobials

**33 Packaging Systems and Storage Times Affect Survival of *Listeria monocytogenes* on Whole Muscle Beef Jerky**. A.S. Lobaton-Sulabo[1], T. Axman[1], K.J.K. Getty[1], E.A.E. Boyle[1], N.M. Harper[1], K.K. Uppal[1,2], B. Barry[2], and J.J. Higgins[1], [1] *Kansas State University, Manhattan,* [2] *Kent, WA*

To validate how packaging and storage reduces *Listeria monocytogenes* (*Lm*) on whole muscle beef jerky, four packaging systems, including heat sealed (HS), heat sealed with oxygen scavenger (HSOS), nitrogen flushed with oxygen scavenger (NFOS), and vacuum (VAC), and four ambient temperature storage times were evaluated. Commercially available whole muscle jerky was aseptically cut into 4 x 4 cm pieces, dipped into a five-strain *Lm* cocktail, and then dried at 25.5°C until an approximate 0.80 water activity was achieved (1-2 h). Jerky was then packaged and stored at 25.5°C. The *Lm* population was enumerated on modified oxford agar at time 0 to determine initial attachment, and at 24, 48, and 72 h, and 30 d after packaging. *Lm* reduction was affected by the interaction of packaging and storage time. Beef jerky packaged in HSOS and VAC had mean *Lm* log reductions of 1.09 and 1.42 log CFU/cm$^2$, respectively following 24 h storage while HS and NFOS had <1.0 log CFU/cm$^2$ reductions. After 48 h, mean log reductions were similar ($p>0.05$) for all packaging systems, ranging from 1.26 to 1.72 log CFU/cm$^2$. By 72 h, mean *Lm* log reductions were >2 log CFU/cm$^2$, except for NFOS with a 1.22 log CFU/cm$^2$ *Lm* reduction. More than a 3.5 log CFU/cm$^2$ mean reduction was observed for all beef jerky packaging systems after 30 d. Processors could package beef jerky in HSOS or VAC in conjunction with a 24 h holding time as an antimicrobial process to ensure a >1 log CFU/cm$^2$ *Lm* reduction or use a 48 h holding time for HS or NFOS packaged beef jerky. Since growth of *Lm* was inhibited for beef jerky as a result of packaging and storage, processors may be able to use selected packaging and storage combinations as an antimicrobial process.

**Key Words**: *Listeria monocytogenes*, packaging, storage, shelf-stable, jerky

**34 Package systems and storage times serve as post-lethality treatments for *Listeria monocytogenes* on smoked sausage sticks.** A. S. Lobaton-Sulabo*[1], E. A. E. Boyle[1], K. J. K. Getty[1], T. Axman[1], K. K. Uppal[1,2], B. Barry[2], and J. J. Higgins[1], [1]*Kansas State University, Manhattan,* [2]*Oberto Sausage Company, Kent, WA.*

To validate how packaging and storage reduces *Listeria monocytogenes* (*Lm*) on shelf-stable smoked sausage sticks, four packaging systems, including heat sealed (HS), heat sealed with

oxygen scavenger (HSOS), nitrogen flushed with oxygen scavenger (NFOS), and vacuum (VAC), and four ambient temperature storage times were evaluated. Commercially available pork and beef smoked sausage sticks with a moisture protein ratio of 0.89, pH of 5.11, and water activity of 0.823 were used. Sausage sticks (14 cm x 1 cm) were inoculated by placing in a stomacher bag containing a five-strain (*Lm*) cocktail, hand massaged, and then air dried at 25.5°C for 1 h. Inoculated smoked sausage sticks were then packaged and stored at 25.5°C. *Lm* populations were enumerated on modified oxford agar at time 0 to determine initial attachment, and at 24, 48, and 72 h, and 30 d after packaging. There was no interaction of packaging system and storage time on *Lm* reduction. Packaging in NFOS, HSOS, VAC, and HS resulted in mean *Lm* log reductions of 1.79, 2.47, 2.74, and 3.01 log CFU/cm$^2$, respectively, regardless of storage time. Sausage packaged in NFOS had a lower ($P<0.05$) mean *Lm* log reduction compared to the other packaging systems. A mean *Lm* log reduction of 2.02, 2.28, 2.47, and 3.25 log CFU/cm$^2$ was achieved after 24, 48, and 72 h, and 30 d of storage, respectively, regardless of packaging system. Increasing storage time from 24 to 72 h or from 72 h to 30 d increased ($P<0.05$) *Lm* reduction in all packaging systems. These results indicate that smoked sausage sticks packaged in HS, HSOS, or VAC, or using a minimum of 24 h storage would achieve >2.0 log CFU/cm$^2$ of *Lm*. This could be used as a *Lm* post-lethality treatment based on USDA FSIS compliance guidelines for RTE meat and poultry products. Processors could also use NFOS as an antimicrobial process since a >1.0 log CFU/cm$^2$ of *Lm* was achieved.

**Key Words:** *Listeria monocytogenes*, packaging, fermented sausage

**35 Scaling-up *Salmonella* lethality calculations from laboratory to pilot-scale slow-cooking processes.** T. J. Breslin*, B. P. Marks, A. M. Booren, E. T. Ryser, and N. O. Hall, *Michigan State University, East Lansing*.

Previous research has shown that sub-lethal heating can increase subsequent thermal resistance of bacteria. If this phenomenon occurs during slow roasting of meat products, it might compromise the validity of thermal process validations. Therefore the objectives of this research were to: (1) evaluate the accuracy of the log-linear inactivation model, developed via prior laboratory-scale, isothermal tests, applied to pilot-scale, slow cooking of whole-muscle roasts, and (2) quantify the variability in results as calculations were scaled-up from laboratory- to pilot-scale tests. Fresh turkey breast and beef rounds were acquired, and 1-2 kg roasts were individually vacuum packaged, frozen (-28°C), and irradiated (>10 kGy). All roasts were kept frozen until 48 h prior to use. Vacuum tumble marination (45 min) was used to inoculate the roasts. The inoculum consisted of an 8-servovar *Salmonella* cocktail in a salt/phosphate marinade (targeting 11.5% salt, 3.7% phosphate). The resulting initial inoculum concentration at the center of the raw roast was 7.0 and 6.5 log(CFU/g) for turkey and beef respectively. This initial concentration subsequently was used in calculating actual log reductions that occurred during the cooking process (initial concentration â□ " final concentration). Following marination, roasts were prepared for cooking. The experimental design consisted of seven different cooking combinations representing industry standards, in-bag or out-of-bag samples at constant temperature (93.3°C) or stepped-up temperature, with and without (98% RH) humidity in a pilot-scale, moist-air convection oven. Core temperature was recorded during cooking via two probes inserted near the center of every roast, and the temperature data from the coldest location was

used to calculate lethality real-time via the log-linear model. When the targeted end point was achieved, roasts were removed from the oven, immediately cored, and cooled. Samples were then diluted 1:5, stomached, plated on duplicate aerobic count Petrifilm$^{TM}$, incubated for 48 h, and enumerated. Estimated lethality, calculated using the log-linear model, was compared to the actual enumerated log reductions, and the mean estimated lethality was greater ($P<0.05$) than the actual lethality. For only turkey, the lethality error was also greater ($P<0.05$) for the cook in-bag treatments than for the no-bag treatments. Additionally, when comparing results from prior laboratory-scale cooking trials that used equivalent inoculum and product types, the replication error for experimental lethality increased with sample size. The replication error for whole-muscle turkey products was 0.82, 1.12 and 1.42 for 1 g, 25 g, and pilot-scale (1-2 kg) samples respectively. Scaling up of cooking processes increases the variability in process validation, which creates a challenge that needs to be considered in the industry when applying lethality parameters determined by laboratory-scale studies. Additionally, the results show that if slow-cooked roasts are processed only to a calculated lethality at or near that required by the regulatory performance standards, *Salmonella* might survive processing.

**Key Words:** *Salmonella*, thermal inactivation, whole muscle

**36 Iron binding by milk mineral: A possible antimicrobial effect in ground beef.** R. Tansawat* and D. P. Cornforth, *Utah State University, Logan.*

Milk mineral (MM) is the dried mineral fraction of ultra-filtered whey. MM is a type II antioxidant which can chelate iron and prevent iron catalysis of lipid oxidation; negatively charged phosphates of MM have high affinity for iron cations. Thus, MM might have antimicrobial effects on iron-dependent bacteria. The objectives of this study were to evaluate the ability of MM to inhibit the growth of non-pathogenic iron-dependent bacteria strains, including *Listeria innocua* ATCC 33090, *Eschericia coli* DH5-α MCR, and *Pseudomonas fluorescens* ATCC 948 and to determine the possible antimicrobial effects of MM against the mixed microflora of fresh ground beef (hamburger patties). Inoculation studies showed that 1.5 % w/v MM did not significantly inhibit growth of *Listeria innocua* in brain heart infusion media and *E. coli* DH5-α in tryptic soy broth incubated at 37°C for up to 48 hours. Growth of *Pseudomonas fluorescens* 948 was not significantly inhibited by 1.5 % w/v MM over the range of $10^3$ to $10^7$ CFU/ml, but a consistent and significant ($P < 0.05$) ~1 log reduction in APC of *Pseudomonas* cultures with all levels of MM (0.5 %, 0.75 %, and 1.5 % w/w) was observed, compared to controls without MM, after 2 days incubation at 22°C. All levels of MM (0.5 %, 0.75 %, and 1.5 % w/w) had no antimicrobial effects against the mixed microflora of fresh ground beef (hamburger patties, 20 % fat) during storage for up to 10 days at 2°C. In conclusion, MM has little or no antimicrobial effect. The strong affinity of MM to ionic iron can inhibit lipid oxidation, but not inhibit bacterial growth supported by other forms of iron (heme or amino acid + iron complexes).

**Key Words:** milk mineral, antimicrobial, *Pseudomonas*

**37 Effect of trisodium phosphate incorporated gelatin coating system as a single**

**antimicrobial intervention on microbial properties of beef steaks.** F. W. Pohlman, A. H. Brown Jr., P. N. Dias-Morse*, L. M McKenzie, L. N. Mehall, and T. N. Rojas, *University of Arkansas, Fayetteville*.

Despite the advances in meat decontamination technology to address pathogenic bacteria, a number of large recalls have caused intense concerns to consumers about meat safety. Therefore, the meat industry continues to seek new and improved technologies to decontaminate meat products. The use of antimicrobial incorporated protein coating systems is a rapidly growing area which offers many advantages over conventional antimicrobial decontamination techniques. Because meat contamination during processing and handling primarily takes place at the surface of the meat products, utilizing an antimicrobial incorporated gelatin coating system prior to packaging could provide an additional measure to improve product microbial safety. Consequently, the objective of this study was to evaluate the effectiveness of a gelatin coating system containing trisodium phosphate (TSP) on reducing *Escherichia coli* and *Salmonella* populations on pre-inoculated beef steak surfaces.
Steaks from strip loins ((IMPS=180; n=90) were inoculated with *Escherichia coli* (EC) and *Salmonella typhimurium* (ST) ($10^7$ CFU/g). The inoculated steaks (n=15/treatment) were dipped in Gelatin with 0% (Gel), 5 % (Gel+5TSP) and 10 % (Gel+10TSP) trisodium phosphate or 10 % trisodium phosphate (10TSP) for 1 min. All the treated steaks and untreated inoculated control steaks (INCON) were packaged and displayed under simulated retail conditions (4 °C)and sampled on day 1, 2, 3 and 7 for EC, ST, coliform (CO) and aerobic plate count (APC).
The GEL+10TSP treatment showed the lowest ($P<0.05$) counts for all the bacteria tested on day 1 of display. The GEL+10TSP and GEL+5TSP treatments outperformed ($P<0.05$) the other treatments in reducing EC, CO and ST counts on day 7 of display. The steaks treated with gelatin+5TSP reported the largest ($P<0.05$) APC reduction (1 log CFU) on day 7. The results indicated that trisodium phosphate incorporated gelatin coating system may improve product safety and extend product shelf life efficiently compared to the direct TSP application or Gelatin coating without TSP.

**Key Words:** beef steaks, antimicrobial coating, microbial quality

**38 Evaluation of alternative cooling procedures for large, intact meat products to achieve stabilization microbiological performance standards.** A. N. Haneklaus*, M. Marquez-Gonzalez, L. M. Lucia, A. Castillo, M. D. Hardin, W. N. Osburn, K. B. Harris, and J. W. Savell, *Texas A&M University, College Station*.

Achieving USDA's Food Safety Inspection Service's stabilization microbiological performance standards proves to be challenging for processors of large, whole-muscle meat products. Exceeding recommended time and temperature limits of a cooling process often results in a deviation from a critical limit and requires corrective actions to be performed on all products associated with the deviation. By examining effects of longer cooling times, alternative times that meet stabilization performance standards may be achieved. This increase in acceptable cooling times will reduce the incidence of deviations and the false assumption of unsafe product. This study was conducted to determine if slower cooling times than those defined by Appendix B could be utilized and still comply with FSIS performance standards. Large (10.43-12.25 kg),

cured bone-in hams (n = 110) and large (≥ 9.07 kg), uncured beef inside rounds (n = 100) were utilized. The study investigated the effect of alternative stabilization parameters on log growth of Clostridium perfringens. Ham stabilization treatments investigated extending the times taken to reduce internal product temperature from 54.5°C to 26.7°C and from 26.7°C to 7.2°C, independently. Further, a worst-case scenario and a control defined by current Appendix B guidelines also were assessed. The worst-case treatment evaluated the effects of cooling product at room temperature (approximately 22.8°C) in place of normal cooling procedures in a temperature controlled environment. Roast beef stabilization treatments investigated extending the times taken to reduce internal product temperature from 54.5°C to 26.7°C and from 26.7°C to 4.5°C, independently. A worst-case scenario also was assessed. Stabilization showed less than 1-log growth of C. perfringens for all treatments, with the exception of the worst-case scenario for roast beef. As expected, > 1 log growth of C. perfringens was reported for uncured roast beef maintained at room temperature for cooling. This study supports product safety with the use of cooling times much slower than those specified by Appendix B. The results demonstrate that industry may have increased flexibility associated with cooling large, whole-muscle cuts while still complying with the required performance standards.

**Key Words:** performance standards, stabilization, C. perfringens

# SYMPOSIA AND ORAL SESSIONS

## : Muscle and Lipid Biology

**1 Maternal protein supplementation at a crucial stage for muscle and fat development diverts adipogenesis to myogenesis in beef steer offspring while not affecting tenderness of *longissimus* steaks.** K. R. Underwood*[1], L. Nicodemus[2], P. L. Price[2], J. F. Tong[2], X. Yan[2], W. J. Means[2], B. W. Hess[2], and M. Du[2], [1]*South Dakota State University, Brookings*, [2]*University of Wyoming, Laramie*.

Early to mid gestation is an important period for muscle and adipose tissue development in beef cattle, hence nutrition during this time is expected to affect muscle and adipose tissue development and consequently carcass characteristics of steers. The objective of this study was to examine how maternal nutrition from day 45 through 185 of gestation, would affect muscle growth and adipose tissue development in steer progeny. Thirty-six crossbred beef cows were randomly assigned to 1 of 3 dietary treatments; control (100% of NRC requirements, C; n = 12), nutrient restricted (70% of NRC requirements, NR; n = 12), or nutrient restricted with a protein supplement (70% of NRC requirements plus supplement, NRP; n = 12) designed to provide duodenal flow of essential amino acids equal to C diet. Following the restriction period, all cows were managed together. Steer calves were weaned at 210 days of age, back-grounded, and placed in a feedlot where they were provided a high energy diet for 195 days. Steers were slaughtered at 405 days of age, *longissimus* muscle (LM) and subcutaneous adipose tissue were collected. Carcass characteristics were measured at 48 hours postmortem and a LM steak was removed, aged 14 days and used for Warner-Bratzler shear force analysis. Subcutaneous adipose tissue and LM were fixed, sectioned, stained and used for analyses of cell number and cell diameter. *Longissimus* muscle homogenate was used for immunoblotting analysis of the signaling

mediators of canonical Wnt pathway, β-catenin and GSK3β. Live weight, hot carcass weight, LM area, skeletal maturity, and marbling score were similar ($P \geq 0.23$) among all treatments. Warner-Bratzler shear force of the LM tended to be less ($P \leq 0.08$) for the C steers when compared to the NR steers. Twelfth rib fat thickness and adjusted 12th rib fat thickness of NR steers was less ($P \leq 0.02$) than C steers and tended to be less ($P \leq 0.08$) than NRP steers. Kidney, pelvic and heart fat percentage was lower ($P \leq 0.05$) for NRP steers compared to C and NR steers. Adipocyte diameter tended to be larger ($P = 0.10$) for NR steers than for NRP steers, and NRP steers tended ($P = 0.09$) to have a greater number of adipocytes per field of view than NR steers. Steers born to NRP dams had heavier *semitendinosus* muscles than C steers ($P = 0.008$) and NR steers ($P = 0.07$). Muscle fiber diameter was similar ($P \geq 0.43$) between treatments, but total muscle fiber number in LM area was higher ($P = 0.02$) in NR steers than C steers. Compared to C steers, NRP steers had higher ($P = 0.01$) and NR steers tended ($P = 0.10$) to have higher β-catenin content. These data show maternal nutrient restriction and protein supplementation during gestation affects muscle and adipose tissue development in beef steer offspring, with protein supplementation diverting adipogenesis to myogenesis.

**Key Words:** adipose tissue, gestational nutrition, muscle growth

**2 Conjugated linoleic acid (CLA) lowers iodine value in pork bellies from pigs fed highly unsaturated fats.** B. R. Wiegand*[1], R. B. Hinson[1], K. S. Roberts[1], H. L. Evans[1], B. Cousins[2], and G. L. Allee[1], [1]*University of Missouri, Columbia*, [2]*BASF Corporation, Florham Park, NJ*.

Literature reports indicate that feeding highly unsaturated fats to pigs will decrease the degree of saturation in pork fat. This decrease in saturation has the potential to soften pork fat and cause processing losses in pork bellies. The objective of this study was to assess the ability of conjugated linoleic acid (CLA) (0.6% of the total diet) to lower iodine value (IV) in pork belly fat, consequently improving fat firmness. Forty barrows were individually penned, fed, and assigned to a 2 x 2 factorial arrangement within a completely randomized design. Factors included dietary fat source (choice white grease (CWG) or soybean oil (SBO)) with or without the inclusion of CLA with 10 replications per treatment. Diets were balanced for lysine content and each contained 4% added fat. Pigs were fed for 60 d prior to slaughter and resulted in 130±2.6kg final body weight. Average daily feed intake (ADFI) decreased (P=0.02) for CLA fed pigs (3.2 kg/d) vs control pigs (3.5 kg/d) from d42-d56. Also, CLA tended (P=0.10) to decrease ADFI from d0-d56 (3.15 kg/d vs 3.32 kg/d for CLA and control pigs, respectively). Carcass measurements of carcass weight, carcass shrink percentage, loin muscle area, tenth rib fat, and last rib fat were not significantly affected by treatment. Also, loin muscle color for Minolta L*, a*, and b* were not affected by treatment. However, loin drip loss % was less (P=0.02) for CLA-fed pigs at 4.09% vs 6.00% for CLA and control, respectively. Iodine value of the belly (sampled posterior to the sternum and anterior to the teat line) increased (P=0.001) with increasing degree of unsaturation in the diet. Feeding CLA decreased IV (P=0.03) from 61.48 to 53.96 in CWG fed pigs and from 68.08 to 64.75 in SBO fed pigs. In conclusion, CLA feeding at 0.6% can decrease ADFI and belly IV in heavy market pigs. Feeding CLA in late finishing pig diets will help avoid undesirable fat quality, especially in pork bellies, when highly unsaturated dietary fats are utilized.

**Key Words:** conjugated linoleic acid, iodine value, pork belly

**3 Mass spectrometric investigations on lipid oxidation-induced carboxymyoglobin oxidation.** P. Joseph*[1], S. P. Suman[1], R. A. Mancini[2], and C. M. Beach[1], [1]*University of Kentucky, Lexington*, [2]*University of Connecticut, Storrs*.

Lipid oxidation generates secondary oxidation products, which compromise myoglobin (Mb) redox stability as well as meat color. 4-Hydroxy-2-nonenal (HNE), a reactive secondary lipid oxidation product, has been utilized as a model aldehyde to investigate lipid oxidation-induced Mb oxidation and subsequent meat discoloration in different species. However, these studies utilized oxymyoglobin (OxyMb) to characterize lipid oxidation-induced Mb oxidation. Carboxymyoglobin (COMb) became highly relevant to the US meat industry since FDA's approval for use of carbon monoxide at 0.4% level in modified atmosphere packaging systems for red meats. Although lipid oxidation-induced browning in COMb is documented, the molecular basis for the interactions between COMb and lipid oxidation products is not clearly understood. Therefore, the objective of the present study was to characterize lipid oxidation-induced oxidation in COMb, in comparison with OxyMb, utilizing mass spectrometry. Equine COMb and equine OxyMb were incubated with HNE (0.15 mM Mb + 1.0 mM HNE) either at pH 5.6 and 4°C (typical meat storage condition) in 50 mM sodium citrate buffer for 8 days or at pH 7.4 and 37°C (physiological condition) in 50 mM sodium phosphate buffer for 6 h. Controls consisted of COMb or OxyMb plus a volume of ethanol equivalent to that used to deliver HNE. Samples (0.25 ml) were removed from the reaction assays at specific time intervals, passed through a PD-10 desalting column, and were analyzed in Matrix Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS) to determine Mb-HNE adduct formation. MALDI-TOF MS spectra revealed that HNE formed mono-, di-, and tri-adducts with COMb at physiological conditions, whereas mono-, di-, tri-, and tetra-adducts were detected in OxyMb. This observation suggested a lower reactivity of HNE towards COMb compared to OxyMb at physiological conditions. In contrast, at meat storage conditions both COMb and OxyMb formed only mono- and di-adducts with HNE, indicating a similar trend for aldehyde adduction. This study, the first to provide evidence for HNE adduction in COMb, suggested that lipid oxidation-induced COMb oxidation is pH- and temperature-dependent. Investigations using tandem MS are underway to determine the amino acids susceptible to HNE adduction in COMb.

**Key Words:** carboxymyoglobin, lipid oxidation, mass spectrometry

**4 Sarcomere length influences hydrodynamic pressure processing tenderization of beef muscle.** B. C. Bowker*, J. S. Eastridge, J. A. Callahan, E. W. Paroczay, and M. B. Solomon, *USDA-ARS, Food Quality Laboratory, Beltsville, MD.*

High energy shockwaves generated by hydrodynamic pressure processing (HDP) have been shown to be effective at tenderizing tough cuts of meat. Variations in the tenderizing effect of HDP are hypothesized to be due to differences in intrinsic muscle characteristics such as the degree of postmortem muscle shortening, the rate and extent of postmortem proteolysis, and

connective tissue. The objective of this two-phase study was to use beef *semitendinosus* (ST) muscle as a model to investigate the influence of sarcomere length on the tenderizing effects of HDP. In the first study, ST muscles (n=8) were divided into sections from the proximal, middle, and distal portions of the muscle. At 4 days postmortem, steaks from each portion were removed to serve as non-treated controls and the remainder of each portion was subjected to HDP treatment. Tenderness measurements at 7 days postmortem indicated that control steaks from the proximal, middle, and distal portions of the muscle did not differ (P>0.05) in Warner-Bratzler shear force (WBSF). The distal portions, however, exhibited greater (P<0.001) WBSF improvements with HDP treatment than proximal portions (23% versus 7% WBSF improvement). In the second study, ST muscles (n=8) were divided into proximal and distal halves and subjected to control and HDP treatments at 4 days postmortem. Sarcomere length was greater (P<0.0001) in the distal portion of the muscle than in the proximal portion (2.42 μm versus 1.89 μm). Similar to the first study, the proximal samples with the shorter sarcomeres exhibited only a small HDP tenderization response (<10% WBSF improvement at day 7 postmortem). WBSF decreased (P<0.01) similarly in both control and HDP samples between 7 and 14 days postmortem. Neither HDP treatment nor sample location (distal versus proximal) influenced collagen content or solubility. Western blot analysis indicated that troponin-T degradation increased (P<0.001) in both control and HDP samples between 7 and 14 days postmortem. Together data from these studies suggest that sarcomere length influences the HDP tenderization effect which is largely due to physical disruptions within the sarcomeric structure.

**Key Words:** tenderness, sarcomere length, hydrodynamic pressure processing

# Tuesday, June 23, 2009

## POSTER PRESENTATIONS

### : Consumer Assessment, Meat Quality, and Muscle Biology

**47 Nutritional and functional attributes of beef kidney and liver from Brazil, Egypt, and United States.** C. R. Raines*[1] and K. Smith[2], [1]*The Pennsylvania State University, University Park,* [2]*U.S. Meat Export Federation, Denver, CO.*

The Arab Republic of Egypt imports a significant tonnage of beef variety meats from various countries. Nutritional and functional attributes of Brazilian (BZ), Egyptian (EG), and U.S. (US) beef kidney and liver were compared. The experiment had a 2 × 3 factorial design ($n$ = 4 replications) with main effects of variety meat (kidney and liver) and origin (BZ, EG, and US). Beef liver and kidney ($n$ = 4 each per origin) were obtained (EG meats were obtained fresh whereas BZ and US were obtained frozen). Total moisture, total protein (dry basis; Kjeldahl), and total fat (dry basis; ether extract) were determined at Cairo University. Total Zn, Fe, P, and vitamins B-1, B-2 , and B-6 were evaluated by personnel at the Egyptian National Nutrition Institute. US liver had more ($P$ < 0.05) moisture than BZ and EG liver. EG kidney had more ($P$ < 0.05) moisture than all other kidneys. There were no differences ($P$ > 0.05) in protein among kidneys from BZ, EG, and US; however, EG and US liver had more ($P$ < 0.05) protein than BZ liver. Liver from BZ had more ($P$ < 0.05) fat than all other livers. EG kidney had more ($P$ <

0.05) fat than all other kidneys. US liver had more ($P < 0.05$) protein and Fe than BZ liver. US liver contained more ($P < 0.05$) Zn and P than BZ and EG liver, as well as more ($P < 0.05$) fat than BZ liver. US and BZ kidneys had greater ($P < 0.05$) vitamin B-1 content than EG kidney. Among kidneys, US had greater ($P < 0.05$) vitamin B-2 and B-6 content than BZ and EG kidney, and US kidney possessed more ($P < 0.05$) fat than EG liver. Liver was also subjected to traditional Egyptian cooking methods (braising, frying, grilling; $n = 4$ replications each) and cook loss was determined. Fried US liver had less ($P < 0.05$) cook loss than BZ and EG fried liver. Braised EG and grilled EG liver had the least ($P < 0.05$) cook loss, BZ liver had the most cook loss, and US liver was intermediate. Sufficient BZ and US braised liver and fried liver remained to conduct a consumer preference test. Panelists ($n = 20$) were asked to rank the liver samples from most to least preferred and to indicate the reason for their ranking. Consumers polled preferred US liver over BZ liver. Ninety-three percent of respondents ranked samples: 1) US liver – fried, 2) US liver – braised, 3) BZ liver – fried, and 4) BZ liver – braised. Respondents indicated that a more tender, softer-textured, and milder-flavored product was their justification for their ranking of US liver over BZ samples. US liver was preferred over BZ liver by Egyptian consumers; it also had less cook loss than BZ liver. US liver possessed greater total protein, Zn, and P, and less fat % than BZ liver. US kidney had superior levels of B-1, B-2 and P than BZ kidney. Beef liver and kidney have certain nutritional and functional attributes related to their origin that can be used as competitive marketing points to Egyptian consumers.

**Key Words:** beef, liver, kidney

**48 A national consumer comparison of USDA Choice vs. Select quality grades of beef.**

J. L. Tedford*, J. C. Brooks, B. J. Johnson, J. D. Starkey, A. Rodas - Gonzalez, G. O. Clark, A. J. Derington, J. A. Collins, and M. F. Miller, *Texas Tech University, Department of Animal and Food Sciences, Lubbock.*

The beef industry needs to characterize consumer palatability ratings and compare U.S. beef quality grades. To accomplish this objective New York Strip lions ( IMPS 180, n=179 ) were collected from numerous beef processing plants (n= 9 ) throughout the United States. The striploins were shipped to the Gordon W Davis Meat Science Laboratory and aged 21 days. Top Loin beef steaks were fabricated from the aged strip loins into steaks with a thickness of 2.54 cm. Steaks were fed to consumers ( n= 642 ) in Baltimore ( n= 214 ), Maryland, Phoenix ( n= 218 ), Arizona, and Lubbock ( n= 210 ), Texas. All steaks were cooked to a medium degree of doneness (71° C) on a commercial clam shell style grill (George Foreman grill model GRP99A). Steaks were trimmed of excess fat and connective tissue and cut into 1 centimeter square cubes and fed to consumers in a cafeteria setting under normal room temperature and lighting. Consumers were asked to give their opinion considering overall like, tenderness like, juiciness like, flavor like, tenderness rating, juiciness rating, flavor rating and likelihood to buy. Choice vs. Select consumer ratings were significantly different for overall like ( 3.4 vs. 3.7 ), juiciness like ( 3.3 vs. 3.6 ), tenderness like ( 3.4 vs. 3.8 ), flavor like( 3.7 vs. 4.1 ), tenderness rating ( 4.1 vs. 4.4 ) and juiciness rating ( 4.4 vs. 4.7 )( P<0.05 ). Lower values indicate greater acceptability. Consumers indicated a trend toward preferring the flavor of Choice over Select in the Flavor Rating ( 4.0 vs. 4.2, P=0.0561 ). Consumers likelihood to buy was significantly greater for Choice steaks when compared to Select steaks ( 2.5 vs. 3.0, P<0.05 ). Consumer demographics

indicated that male consumers had greater acceptance for overall like of both Choice and Select steaks vs female consumers ( Choice 84.4% vs. 79.3%, Select 73.6% vs 71.0% ). Consumers with lower income levels had higher overall like acceptability scores for Choice beef and showed greater differences for Choice vs Select grades ( Choice 93.3% vs 73.6%, Select 69.6% vs. 71.6% ). Consumers with higher incomes had similar overall like ratings for both Choice and Select quality grades ( Choice 73.6%, Select 71.6% ). Similarly, consumers with less education showed the greatest differences between Choice and Select steaks for overall acceptability ( Choice 83.9% vs. 75.9%, Select 65.8% vs. 71.7% ). Also, consumers that indicated they eat beef more frequently during the week were able to show the greatest differences between Choice steaks with no difference for Select steaks ( Choice 0 – 2 times per week: 75.8% vs 7+ times per week: 83.3%, Select 0 – 2 times per week: 70.5% vs. 7+ times per week: 68.0% ). In this nation wide study, consumers prefered to eat USDA Choice before USDA Select steaks.

**Key Words:** quality grade, consumer

**49 Consumer assessment of beef tenderloins from various grades.** T. G. O'Quinn*, J. C. Brooks, B. J. Johnson, J. Starkey, and M. F. Miller, *Texas Tech University, Lubbock.*

A consumer study was conducted to determine consumer palatability ratings of beef tenderloin steaks from USDA Choice, USDA Select, and USDA Select with marbling from Slight [50-99] cooked to various degrees of doneness. Steaks (n = 420) weighing approximately 200 g were randomly assigned to one of three degree of doneness categories: rare (60 C), medium (70 C), and well-done (75 C). Steaks were prepared on a flat-top grill by professionally trained chefs from a major steakhouse chain. Each steak was seasoned with a spice blend prior to cooking and a ladle (30 ml) of butter was placed on the grill immediately prior to cooking and at turning. The degree of doneness was determined visually by comparison to the National Live Stock and Meat Board's Beef Steak Color Guide. Each steak was divided into three, equally-sized portions and fed to consumers. Consumers (n = 315) were screened for preference of degree of doneness and upon screening, were fed four samples of their preferred doneness, (a warm-up sample, and one sample from each USDA quality grade treatment) in a random order. Consumers evaluated steaks on an 8-point hedonic scale for tenderness, juiciness, beef flavor, and overall palatability as well as rated the steaks as acceptable or unacceptable for all palatability traits. USDA quality grade treatments had no effect on tenderness, juiciness, beef flavor, and overall palatability scores. Consumers also found no differences in percent acceptability of palatability traits between USDA quality grades. Steaks cooked to a well-done degree of doneness had lower ($P < 0.05$) juiciness scores than steaks cooked to rare or medium degrees of doneness and were ranked tougher ($P < 0.05$) than steaks cooked to a rare degree of doneness. Results indicate consumers were not able to detect differences in tenderness, juiciness, beef flavor, or overall palatability among beef tenderloin steaks from USDA Choice and Select quality grades. Results also indicate the percentage of tenderness, juiciness, beef flavor and overall acceptability of palatability traits do not differ by USDA quality grade when steaks are prepared as described. Finally, consumers rated tenderloin steaks cooked to a well-done degree of doneness as less juicy than steaks cooked to rare or medium degrees of doneness and tougher than steaks cooked to a rare degree of doneness regardless of their degree of doneness preference.

**Key Words:** tenderloin, consumer, palatability

**50 Restaurant patrons' perceptions of North Dakota and guaranteed tender labeling relative to price paid and palatability.** A. N. Lepper*, R. J. Maddock, and E. P. Berg, *North Dakota State University, Fargo*.

The objective of the study was to determine if restaurant consumers are willing to pay a premium for North Dakota-raised, known-tender steaks and, if so, to identify their perception of tenderness, juiciness and flavor. Three restaurants in Fargo, North Dakota were selected based on menu ribeye price and willingness to collaborate. Restaurants were classified into one of three categories: high steak cost (≥$25.00); medium ($15.00 to $24.00); and low (≤$15.00). The "North Dakota Tendercut" ribeye steak was offered as an evening feature at each restaurant on Thursday, Friday, and Saturday nights on three non-consecutive weeks. The price of the North Dakota Tendercut ribeye was 10, 20, or 30% higher than the restaurant's regular ribeye menu item. After patrons consumed their meal, they were asked to fill out a survey consisting of eight questions regarding their eating experience. The second question of the survey asked the consumers to rank the following factors in order from 1 to 7 based on their purchasing decision: price, it was a featured beef item, was a North Dakota product, was classified as tender, waitress/waiter recommendation, suggested by a friend, and other. Across all restaurants 116 ribeye steaks were sold. Survey results found that consumer purchasing decisions were affected, in order by: North Dakota product (30%), staff recommended (25%), tender (16%), featured item (15%), friend (7%), price (4%), and other (4%). Consumers were asked to rank tenderness, juiciness, and flavor on a scale from 1 to 9 with 9 being the highest value for each category. Consumers rated steaks higher in tenderness ($P = 0.05$) as purchase price increased. Furthermore, there was a tendency to rate steaks higher in juiciness ($P = 0.09$) and flavor ($P = 0.08$) respectively as purchase price increased.

**Key Words:** beef, ribeye, consumer preference

**51 Consumer preference of steaks cut to a constant weight from different carcass weight groups.** J. M. Behrends*, C. M. Leick, M. W. Schilling, S. Yoder, and T. Schmidt, *Mississippi State University, Mississippi State*.

The objective of this study was to evaluate consumer's preference of strip loin, ribeye, and top sirloin steaks, in a retail setting when steaks were cut to a constant weight. Five carcasses were selected from each of the following weight and ribeye groups to obtain a range of steak sizes and thicknesses (G1 – 226 to 271 kg/70.9 – 78.1 $cm^2$ ; G2 – 272 to 316 kg/78.7 – 85.8 $cm^2$; G3 – 317 to 361 kg/86.5 – 93.5 $cm^2$; G4 – 362 to 407 kg/94.2 – 101.3 $cm^2$; G5 – 408 to 452 kg/101.9 – 109.3 $cm^2$). All carcasses were a yield grade of 1 or 2 and a USDA quality grade of Low Choice. All subprimals (Ribeye Roll, IMPS 112A; Striploin, IMPS 180; and Top Butt, IMPS 184) were further processed into individual steaks that weighed 345 g each for ribeye and strip loin steaks and 284 g each for top sirloin steaks. Steaks were individually packaged in Styrofoam trays and over-wrapped with PVC. Two steaks from each carcass (n=50/steak type) were randomly selected and displayed for consumer preference testing. Consumers were asked to select three

steaks from each steak type and rank their selections based on color, marbling, texture, and thickness. As weight groups and ribeye requirements went up steaks decreased in thickness and increased in surface area. Based on carcass groups, consumers selected ribeye steaks from G5 more often ($P<0.05$) than any other carcass group. There were no differences ($P>0.05$) based on carcass group for strip loin and sirloin steaks. Male consumers selected ribeye steaks from heavier weight groups (G4 and G5) more frequently ($P<0.05$) than other weight groups, whereas female consumers did not have a preference for ribeye steaks. Also, male and female consumers showed no preference ($P>0.05$) among weight groups in there selection of strip loin and sirloin steaks. Consumers making less than 20,000.00/year selected ribeye steaks and sirloin steaks from G5 more than any other carcass group. Steaks from G5 had an increase in surface area and may have given the appearance that the steak was heavier in weight. There was a tendency ($P=0.06$) for those making under $20,000/year to select strip loin steaks from G3 and G4 a higher percentage of the time than other groups. Consumers under the age of 20 selected ribeye steaks from G5 more ($P<0.05$) than any other carcass group. Consumers between the age of 40 and 49 tended ($P=0.07$) to select steaks from G3, G4, and G5. There were no differences ($P>0.05$) in selection percentage of ribeye, strip loin, or sirloin steaks by panelists relative to their reported beef consumption history. Further investigation of consumer markets should provide descriptive data to elucidate consumer preferences. A better understanding of consumer preferences will add value to the beef industry by improving sorting and marketing of products to target specific end uses.

**Key Words:** beef, consumer, carcass weight, steak thickness

**52 Consumer preference of steak thicknesses cut to a constant weight based on price.** J. M. Behrends*, C. M. Leick, M. W. Schilling, S. Yoder, and T. Schmidt, *Mississippi State University, Mississippi State*.

The objective of this study was to evaluate consumer's preference of strip loin, ribeye, and top sirloin steaks, in a retail setting based on premiums for thickness. Five carcasses were selected from each of the following weight and ribeye groups to obtain a range of steak sizes and thicknesses (G1 – 226 to 271 kg/70.9 – 78.1 $cm^2$ ; G2 – 272 to 316 kg/78.7 – 85.8 $cm^2$; G3 – 317 to 361 kg/86.5 – 93.5 $cm^2$; G4 – 362 to 407 kg/94.2 – 101.3 $cm^2$; G5 – 408 to 452 kg/101.9 – 109.3 $cm^2$). All carcasses had a yield grade of 1 or 2, and a USDA quality grade of Low Choice. All subprimals (Ribeye Roll, IMPS 112A; Striploin, IMPS 180; and Top Butt, IMPS 184) were further processed into individual steaks weighing 345 g each for ribeye and strip loin steaks and 284 g each for top sirloin steaks. Steaks were individually packaged in styrofoam trays and over-wrapped with PVC. Steaks were sorted by thickness and ten of each steak type were assigned to each of the three price labels (thin = $8.99/lb ribeye and strip steaks and $4.99/lb sirloin steaks; average = $9.99/lb ribeye and strip steaks and $5.99/lb sirloin steaks; thick = $10.99/lb ribeye and strip steaks and $6.99/lb sirloin steaks). Steaks were displayed and consumers were informed that all steaks weighed the same and weight and price were marked on each retail package. Consumers were asked to select the three steaks they would purchase from each of the steak types and rank their selections based on price, color, marbling, texture, and thickness. There were no differences ($P>0.05$) between male and female consumers for ribeyes based on price; however, 54.3 % of males and 54.5 % of females were willing to pay at least a $1.00/lb premium

for the ribeye steaks they selected. Similarly, there were no differences (P>0.05) between males and females for strip loin steaks based on price; however 68.4 % of males and 61.2 % of females selected strip steaks with a premium of $1.00/lb or more. Age groups included group 1 (under 20 years), group 2 (20 – 29 years), group 3 (30 – 39 years), group 4 (40 – 49 years), group 5 (50 – 59 years), and group 6 (60 years or older). Age groups 1, 2, 4, and 5 (27.6%, 21.5%, 16.2%, and 28.0%, respectively) were less likely to select the highest priced thickest ribeye steaks. There were no differences (P>0.05) among age groups for percentage of consumers selecting strip loin steaks and sirloin steaks for any premium thickness group. For ribeye steaks, differences (P<0.05) only existed between consumers that earned less than $20,000/year or more than $60,000/year, with both groups selecting the lowest price steaks more often than the highest price steaks. There were no differences (P>0.05) among income groups in the selection of sirloin steaks or strip loin steaks. Consumers that consumed beef 2, 3, and 4 times a week were more likely to select sirloin steaks from the middle priced group. The same trend was not observed in the ribeye steaks or strip loin steaks. Consumers who consumed beef more than four times a week were most likely to select the lowest priced (thinnest) ribeye steak. Consequently, more than 50% of consumers pay at least a $1.00 premium for steaks based on color, marbling, texture and thickness. Additional research should identify price points on beef steaks purchased by specific consumer groups and target premiums accordingly.

**Key Words:** beef, consumer, price, steak thickness

**53 Effect of antemortem acute cold stress, age, sex, and lairage on broiler breast meat quality.** S Dadgar*, E. S. Lee, T. L. V. Leer, N Burlinguette, H. L. Classen, T. G. Crowe, and P. J. Shand, *University of Saskatchewan, Saskatoon, SK, Canada*.

Transportation during Canadian winters may affect broiler chicken welfare and subsequent meat quality. Effect of acute cold exposure on welfare (body temperature), breast meat quality and muscle metabolites were assessed on broiler chickens at two ages (5 and 6 weeks old with average weight of 1.88 and 2.63 kg, respectively) by exposing 360 birds to temperatures from -18 to +20°C in a simulated transport system for a duration of 3 h. Birds were assigned to either 0 or 2 h of lairage prior to processing. Core body temperature was recorded with a temperature logging Thermocron iButton® (DS1922L iButton Â®, Maxim Integrated Products, CA) orally dosed into the proventriculus of each test bird. The temperature and relative humidity (RH) near each bird was monitored with similar data loggers. Apparent equivalent temperature (AET) calculated based on the temperature and RH surrounding individual birds was used to classify birds into 5 groupings with average AETs of
-14, -11, -8, 0 and 30°C. The core body temperature of birds dropped significantly (P<0.0001) during the 3 h exposure time as AET decreased. The effects of AET on meat quality parameters were affected by age of the birds. Breast meat of birds at 5 weeks of age was significantly (P<0.0001) higher in ultimate pH (pHu), darker and redder with lower cook loss and higher water binding capacity (WBC) for birds exposed to average AET below -8°C compared to warmer AETs. However, for 6 week-old birds, similar results were observed only when AET dropped below -11°C. Breast meat drip loss, thaw loss and texture parameters did not show any significant trend based on exposure temperature. Moreover, sex of the birds significantly (P<0.0001) influenced the core body temperature and meat pHu, with males having greater drop

in core body temperature and higher breast meat pHu compared to females. Muscle metabolites, including ultimate glycolytic potential and lactate concentrations (measured 30 h postmortem), were lower for birds exposed to average AETs below -11°C, showing that such birds had lower energy reserve at the time of slaughter. Lairage also showed significant ($P<0.0001$) effect on core body temperature by causing further drop during lairage when AET reached below -8°C for 5 week-old birds and below -11°C for the 6-week old birds. In addition, lairage caused a significant increase in pHu and WBC of meat at average AET values below -11°C. Breast meat with pH > 6.1 and L* < 46 was considered to be dark, firm and dry (DFD). Both ages showed a very high (>57%) incidence of DFD breast meat when the average AET dropped below -14°C, whereas at an average AET of -11°C, younger birds had DFD incidence of 71% compared with only 24% for the 6-week old birds. Results of this study showed that older birds (heavier bird with more feather coverage) could cope better with extreme cold conditions compared to younger birds. Furthermore, contrary to a common belief, it might be beneficial to limit the length of lairage prior to processing following acute cold stress during transportation to improve welfare and reduce meat quality defects.

**Key Words:** cold stress, broiler chicken, meat quality

**54 Impact of deboning time on breast fillet dimensions from commercial broilers of small and big bird markets.** V. B. Brewer*, V. A. Kuttappan, J. L. Emmert, and C. M. Owens, *University of Arkansas, Fayetteville*.

There is a high demand for boneless broiler breast meat and this has led to shortened aging periods in efforts to better streamline production. It is well documented that pre-rigor deboning leads to shorter sarcomeres and tougher meat. Fillet dimensions are of interest to breeders for breeding programs and to processors due of the high demand of portioned products. The purpose of this study was to assess the impact of deboning time on fillet dimensions. Two trials were conducted using commercial broiler strains reared to simulate small and big bird market programs. For the small bird trial, 1,080 broilers ( male and female), were grown to 40 d and for the big bird trial, 1,440 broilers (male and female) were grown to 60 d. In each trial, broilers were processed using standard commercial practices including electrical stunning, defeathering, evisceration, and chilling for 1.5 h to reach an internal temperature of 4°C. Breast (*Pectoralis major*) fillets were deboned at 2, 4, and 6 h postmortem (PM). Fillets were individually packaged and aged on ice in a 4°C cooler. Fillet length, width, and depth at three locations, the thickest portion at the cranial end, one inch from the bottom at the caudal end, and equidistant between these locations, were measured. All fillet dimensions were measured 24 h PM using calipers. Fillet dimensions were affected by deboning time in each trial. In the big bird trial, the fillets were significantly ($P<0.05$) shorter at 2 h PM compared to fillets deboned at 4 or 6 h PM; however, there was no impact on the length of fillets in the small bird trial due to deboning time. In both trials, deboning at 2 h PM resulted in narrower fillets that were also thicker ($P<0.05$), likely attributed to sarcomere shortening caused by pre-rigor deboning. This trend continued as the fillets deboned at 4 h PM were narrower and thicker ($P<0.05$) than fillets deboned at 6 h PM. In conclusion, pre-rigor deboning does impact fillet dimensions and the results suggest that the effect is more drastic in big bird programs.

**Key Words:** dimensions, poultry meat, deboning

**55 Nutrient composition of enhanced and non–enhanced boneless skinless chicken breast fillets purchased from retail.** M. D. Cael*[1], J. C. Howe[2], K. Y. Patterson[2], J. M. Holden[2], B. Showell[2], A. M. Luna[1], and L. D. Thompson[1], [1]*Texas Tech University, Lubbock*, [2]*USDA/ARS Beltsville Human Nutrition Research Center, Beltsville, MD.*

The objective of this study was to compare the nutritional composition of raw enhanced (E) and non–enhanced (NE), boneless, skinless chicken breast fillets (*pectoralis major*), obtained from U.S. retail supermarkets. Fillets were either enhanced with a salt, phosphate and water solution, or were non–enhanced. Sampling locations utilized were those previously identified and used by USDA to collect data for the USDA National Nutrient Database for Standard Reference. Enhanced or NE samples were randomly assigned to be purchased as follows: E samples were obtained from four retail supermarkets located in Michigan, North Carolina, Colorado, and Florida, and NE samples were from four retail supermarkets in New York, Michigan, Missouri, and Oklahoma. Samples were shipped frozen on dry ice to Texas Tech University (TTU). Upon receipt, samples were homogenized, stored at –80°C, and subsequently shipped on dry ice to USDA–contract laboratories for analysis of moisture, protein, ash, minerals, lipids, and vitamins. Samples retained at TTU were analyzed for cholesterol. Percentage moisture, ash, protein, and fat of the raw fillets were not different between E and NE fillets, averaging 76.36%, 1.32%, 20.50%, and 2.66%, respectively ($P \geq 0.05$). Based on the proximate analysis, a 100–g serving of the raw fillets contained 106 kcal. Lipid profile was unaffected ($P \geq 0.05$) by enhancement, with lipids averaging 32.5% saturated, 44.5% monounsaturated and 23.0% polyunsaturated fat, and average trans fat content was 0.024 g/100 g. Cholesterol content averaged 61.5 mg/100 g. Enhancement increased ($P \leq 0.05$) P and Na contents of breast fillets 24% and 178%, respectively (mean±SEM; E = 259.9±16.1 vs. NE = 209.5±9.8 and E = 322.5±52.0 vs. NE = 116.1±31.9). Enhancement decreased K content of fillets by 24% (E = 281.5±7.4 vs. NE = 370.3±22.5, $P \leq 0.05$). Calcium, Fe, Mg, Zn, Cu, Mn, and Se were unaffected ($P \geq 0.05$) by enhancement with fillets averaging 4.48, 0.36, 24.6, 0.56, 0.03, 0.028 mg/100 g, and 27.3 mcg/100 g, respectively. Vitamins (thiamin, niacin, pantothenic acid, B6, B12, and retinol) were unaffected by enhancement with the exception of riboflavin which was lower in E compared to NE fillets (0.083±0.002 vs. 0.100±0.007 mg/100 g, respectively, $P \leq 0.05$). Phosphorus, Na, K, and riboflavin were the nutrients affected by enhancement. Consumers and health care professionals should be aware that enhancement of poultry, while desirable for maintaining tenderness and juiciness of the cooked product, has a significant impact on the P and Na content of the product, and this could have an effect on dietary needs or restrictions.

**Key Words:** nutritional composition, enhancement, chicken breast fillet

**56 Oleic acid enhances adipogenic gene expression but reduces AMPKα protein expression in muscle cell cultures.** K. Y. Chung*, K. M. Janota, G. H. Hwang, and B. J. Johnson, *Texas Tech University*, *Lubbock.*

Previous research indicates that cattle, such as the Waygu breed, with higher degrees of

intramuscular adipose tissue also possessed higher concentrations of oleic acid, a monounsaturated, omega-9 fatty acid. Current research is being conducted to evaluate possible methods to enhance adipogenic gene expression in cattle to further enhance marbling. Under appropriate stimuli, skeletal muscle progenitor cells have the capability to become a variety of cell types. It has been reported that these particular cells may be induced and complete the adipose tissue pathway, to form marbling, rather than following the skeletal muscle pathway. We hypothesized that muscle satellite cells would differentiate and express higher levels of adipogenic gene expression such as PPARγ (peroxisome proliferator-activated receptor) when treated with concentrations of oleic acid. Protein and RNA were extracted from individual treatments and prepared for Western blot and Real-time PCR analysis, respectively. It was found that C2C12 cells had higher levels of GPR43 ($P < 0.05$) and PPARγ ($P < 0.05$) when concentrations of oleic acid were greater. However, relative RNA level of myogenin was decreased at the high dosage of oleic acid. High dosage of oleic acid decreased the protein level of AMPKα in the C2C12 cell. In contrast, oleic acid treatments increased AMPKα protein level in the 3T3-L1 cell. Throughout this experiment, multiple mouse cell lines, including C2C12, and 3T3L1, were treated with different concentrations of oleic acid, ranging from 1 μM to 500 μM. 10T 1/2 and bovine muscle derived cell with oleic acid increased both GPR43 ($P < 0.05$) and PPARγ ($P < 0.05$) in gene and protein expression compare to other fatty acid treatments. The data indicated that oleic acid treatment enhanced adipogenesis in mouse myoblast cells but reduced lipogenesis in mouse adipoblast cells. These results suggest that oleic acid treatment enhances GPR43 but inhibits AMPKα in bovine satellite cell and differentially affects lipogenesis in mouse muscle cell and adipocyte.

**Key Words:** AMPK, GPR43, muscle cell culture

**57 Effects of electrical stimulation and postmortem ageing on RNA integrity and DNAJA1 mRNA in two beef muscles.** A. S. Sami[1], C. R. Raines*[2], E. W. Mills[2], B. W. Infantolino[2], T. L. Ott[2], and A. N. Gipe[2], [1]*Cairo University, Giza, Egypt*, [2]*The Pennsylvania State University, University Park.*

The DNAJA1 gene has been identified as a possible marker for predicting meat tenderness. DNAJA1 codes for Heat Shock Protein 40, which may hinder postmortem meat tenderization. The objective was to evaluate the effects of electrical stimulation (ES) and postmortem ageing (PA) on DNAJA1 mRNA concentrations and by evaluating RNA integrity in beef. Five Angus steers (615 kg of BW ± 27 kg; 15 mo age) were fed a commercial finishing diet for 258 d and harvested at the Penn State University Meats Laboratory. The experiment had a $2 \times 2 \times 10$ factorial design with main effects of ES (non- and stimulated), muscle (*Longissimus dorsi* - LD, and *Biceps femoris* - BF), and PA (0, 1, 3, 6, 9, and 24 h, and 3, 7, 14, and 21 d). Left carcass sides were not ES (NES) and right carcass sides were ES (350 V, 3 cycles, 30 s/cycle) 20 min postmortem, then chilled at 4°C for 24 h. LD and BF samples were taken from NES and ES sides at 0, 1, 3, 6, 9, and 24 h and were homogenized in TRIzol reagent and directly kept at -80°C for the next steps of RNA extraction. After 24 h, LD and BF muscles were removed from NES and ES sides and cut into 2.54 cm-thick steaks. Steaks were vacuum packaged and randomly assigned to 3, 7, 14, and 21 d ageing periods, and stored at 4°C. After ageing, samples were frozen (-20°C) until further analyses, homogenization and RNA extraction could occur. RNA

integrity number (RIN) determined by the 28S:18S ratio and DNAJA1 mRNA concentrations of LD and BF steaks at 0, 1, 3, 6, 9, and 24 h, and 3, 7, 14, and 21 d postmortem ($n$ = 200; 5 animals × 2 sides × 2 muscles × 10 sampling PA) were measured. Sarcomere length and WBSF of LD and BF steaks aged 1, 3, 7, 14 and 21 d postmortem ($n$ = 100; 5 animals × 2 sides × 2 muscles × 5 sampling PA) were measured. There was a 3-way interaction ($P < 0.05$) for ES × muscle × PA for RIN, where RIN decreased ($P = 0.02$) faster for ES carcasses, faster in LD, and decreased over PA. A muscle × PA interaction affected the 28S:18S rRNA as shown by decreased ($P < 0.001$) values with PA and for LD. DNAJA1 mRNA concentration was greater ($P < 0.001$) in muscle aged for shorter periods of time. Sarcomeres were longer ($P < 0.01$) in muscle from NES sides than ES sides. There were main effects ($P < 0.05$) of ES, muscle, and PA for WBSF values. ES muscles were less tender ($P = 0.012$) than NES muscles. LD was more tender ($P < 0.001$) than BF and steaks became more tender ($P = 0.011$) with increased PA. ES decreased sarcomere length and tenderness, accelerated RIN reduction compared with NES, and RIN decreased with PA. Although beef tenderness may be predicted by evaluating DNAJA1 mRNA, postmortem processes such as ES affect the integrity of this and other mRNAs and may, therefore, result in inaccurate tenderness predictions.

**Key Words:** electrical stimulation, RNA integrity, DNAJA1

**58 *In vitro* degradation of bovine myofibrils is caused by μ–calpain, not caspase–3.** D. A. Mohrhauser*, D. M. Wulf, and A. D. Weaver, *South Dakota State University, Brookings*.

Tenderness is a key palatability trait influencing consumers′ perception of meat quality and is influenced by a multitude of factors, including postmortem proteolysis. A fundamental understanding of this biological mechanism regulating tenderness is necessary to decrease variability and increase consumer satisfaction. However, reports regarding the enzyme systems involved in postmortem tenderization are conflicting. Therefore, the objective of this study was to determine if caspase–3 is responsible for the degradation of myofibrillar proteins during aging. Bovine *semitendinosus* muscles were removed from two carcasses. Muscle from the left side of each carcass was excised 40 min postmortem and utilized for *in vitro* analysis of protein degradation. Muscle strips (30–cm long by 1–cm in diameter) were dissected from the *semitendinosus*, restrained to maintain length, and placed in a neutral buffer containing protease inhibitors. Upon rigor completion, myofibrils were isolated from each strip and sarcomere length was determined. Samples with similar sarcomere lengths were selected to minimize the effect of sarcomere length on proteolysis. Myofibrils were then incubated at 22°C with μ–calpain, caspase–3, or μ–calpain + caspase–3 for 0.25, 1, 3, 24, 48, or 72 hours at optimum pH for enzyme activity. The *semitendinosus* from the right side of each carcass was excised 1d postmortem, cut into 2.54–cm steaks, vacuum packaged and allowed to age for 2, 4, 7, or 10 days to evaluate *in vivo* protein degradation. Proteolysis of troponin–T, α–actinin, and desmin was monitored using SDS–PAGE and western blotting for all samples. Analysis of western blots revealed no change in abundance of intact troponin–T or desmin over time in myofibrils incubated with caspase–3. However, abundance of these proteins subjected to digestion with μ–calpain and μ–calpain + caspase–3 revealed degradation patterns similar to *in vivo* samples. No degradation of α–actinin was observed in either *in vitro* or *in vivo* samples. Results of this study indicate μ–calpain, not caspase–3, is responsible for degradation of specific myofibrillar proteins

during beef aging.

**Key Words:** caspase, μ–calpain, proteolysis

**59 Proteomic analysis of bovine muscles during aging.** M. J. Anderson*, T. J. Grevengoed, S. M. Lonergan, and E. Huff-Lonergan, *Iowa State University, Ames*.

The objective of this study was to determine the identity of proteins that are altered during the postmortem aging process in muscles that differ in tenderness and postmortem protein degradation. The *adductor* (AD) was chosen because it showed very little change in tenderness and degradation of troponin-T and desmin from 1 to 14 d postmortem. Conversely, the *longissimus dorsi* (LD) was chosen because it showed a large increase in tenderness and degradation of troponin-T and desmin from 1 to 14 d postmortem. In both the AD and LD, samples from 5 carcasses were selected from a larger study. Samples chosen represented the average tenderness for each specific muscle. From each muscle two protein fractions were extracted, a highly soluble sarcoplasmic fraction, and a less soluble, crude myofibrillar fraction. 1 and 14 d samples from the same muscle and protein fraction were run on the same 2D gel. Gels were analyzed with the DeCyder™ 2D software v6.5 (GE Healthcare, Piscataway, NJ). Differences between days were analyzed using Student's paired t-test to determine the changes in resolved protein relative abundance during aging in each muscle. Proteins were identified using electrospray ionization mass spectroscopy. Aging in the AD resulted in few detectable differences in the sarcoplasmic or myofibrillar protein profile. In both the AD and LD, a decrease ($P < 0.1$) in the relative abundance of glyceraldehyde-3-phosphate dehydrogenase in the sarcoplasmic fraction and an increase ($P < 0.1$) in relative abundance in the myofibrillar fraction due to aging was noted, suggesting that a change in solubility of glyceraldehyde-3-phosphate dehydrogenase had occurred. In the myofibrillar fraction of the LD, there was a decrease ($P < 0.05$) in the relative abundance of myomesin over time. In the sarcoplasmic fraction of the LD the relative abundance of myomesin increased ($P < 0.05$) over time. Aging from 1 to 14 d postmortem resulted in a 1.44 fold decrease ($P < 0.05$) in the relative abundance of a fragment (150 kDa) of myosin heavy chain-1. In the sarcoplasmic fraction of the LD, alpha actinin-3 had a 1.67 fold increase ($P < 0.05$) in relative abundance over time. In the LD, a number of enzymes involved in glycolysis, including fructose-bisphosphate aldolase (myofibrillar), and phosphoglycerate kinase 1 (sarcoplasmic), were found to decrease ($P < 0.1$) in relative abundance over time. Other glycolytic enzymes in the sarcoplasmic fraction of the LD, including malate dehydrogenase, and triosephosphate isomerase, increased ($P < 0.05$) in relative abundance due to aging. These data suggest that analysis of only part of the proteomic profile could lead to falsely concluding that a protein had been degraded when only a change in protein solubility has occurred. Changes in protein profile due to postmortem aging may be the result of differences in protein solubility as well as degradation.

**Key Words:** 2D DIGE, tenderness, beef

**60 Effect of high pressure treatment on the eating quality of the longissimus muscle.** B. J. Fleer[1], M. Zeece[1], S. Jung[2], and S. J. Jones*[1], [1]*University of Nebraska, Lincoln*, [2]*Iowa State*

*University, Ames.*

Effects of high pressure (HP) treatment on bovine longissimus muscle (LD) were examined for changes in eating quality. USDA select beef rib- eyes (112A) were obtained from a commercial packing plant and transported to the University of Nebraska laboratory. The longissimus muscle was removed 36 h post-mortem, sliced into 10 regions (approximately 200 g), vacuum packaged and stored at 4°C. Twenty four hours after packaging the samples were treated with 5 different levels of pressure (0.1, 100, 200, 300 and 400 MPa) at an initial temperature of 10°C for five minutes. One group of samples from each pressure treatment were frozen immediately and a second group aged fourteen days at 4°C. Tenderness (Warner Bratzler Shear, WBS), lipid oxidation (thiobarbituric acid, TBA), collagen solubility, and sensory analysis were performed. Shear force values were significantly higher ($P<.01$) between 400 MPa and 0.1 MPa after 14 days of storage, however, this response was not observed in the 0d aging treatment. TBA values were significantly higher ($P<0.05$) between 0.1 MPa and 400 MPa at day 14, however, a similar trend was not observed with unaged samples. Collagen solubility was unaffected by HP, however, aging increased solubility ($P<.05$). Panelists perceived differences in chewiness, flavor and overall acceptability with 0.1 MPa and experimental day 0 most acceptable. Overall, HP treatments increased lipid oxidation, shear force and had a lower consumer appeal.

**Key Words:** high pressure, tenderness, lipid oxidation

**61 Beef tenderization potential of *Calocybe gambosa*.** J. Y. Jeong* and J. R. Claus, *University of Wisconsin, Madison*.

The tenderization effect on intact beef and proteolytic breakdown profile in lean minced beef associated with the incorporation of mushroom extract prepared from *Calocybe gambosa* was studied. Prechilled strip loins, eye of rounds, and an intact beef chuck (15% fat) were obtained from a Wisconsin processor (2-day postmortem). Five strip loins and eye of rounds were cut into duplicate 2.5-cm thick streaks. Five strip loins (SL) steaks and eye of rounds (ER) steaks were hand injected with 12% mushroom (*Calocybe gambosa*) extract or distilled water (Control) based on the meat weight. After incubating (24 h, 2-3°C), steak samples were analyzed for pH, injection yield, cooking loss, and Warner-Bratzler shear force (WBS). Intact beef chuck was ground (0.32-cm plate), vacuum-packaged, and then frozen (-18°C) at 4-day postmortem until used. Ground beef after thawing (36-48 h, 2-3°C) was mixed with 10% mushroom extract or distilled water (Control). Treated ground beef was incubated (24 h, 2-3°C), and then sampled (0, 24 h) for SDS-PAGE gel electrophoresis using an 8% acrylamide gel. Dried mushroom was pulverized with liquid nitrogen using a mortar. Five grams of fine *Calocybe gambosa* powder were mixed with 30mL of distilled, deionized water. Mixtures were homogenized, centrifuged (2,000 × g, 10 min), and then the supernatant was filtered. Steaks were cooked to an internal temperature of 71°C on an electric grill and cooled for 90 min at room temperature before sampling for Warner-Bratzler shear force. Six to eight strips (1 cm wide and thick) per each SL or ER steak were removed parallel to muscle fibers for shearing perpendicular to the muscle fibers.
Mushroom treated steaks had a limited effect on meat pH values. Compared to the control steaks, mushroom treated steaks had higher ($P < 0.05$) injection yield (104.6% versus 101.6%, SL;

105.1% versus 102.2%, ER), but showed higher cooking loss (35.6% versus 25.8%, SL; 40.0% versus 31.4%, ER). Addition of the mushroom extract dramatically increased steak tenderness (lower WBS values) for SL (52%) and ER (33 %) compared to the control (35.8 N, SL; 45.5 N, ER). Moreover, tissue in localized areas in the cooked steaks appeared to be completely broken down (myofibrillar and connective tissue) producing areas with a mushy, pasty texture. For electrophoresis analysis, ground beef treated with mushroom extract showed the remarkable degradation of myofibrillar proteins at 24 h of incubation, especially for myosin heavy chain. Smaller molecular weight bands were more intense (90-150 kDa range) in mushroom treated ground beef. The appearance of these bands was most likely because the extract from *Calocybe gambosa* had a significant amount of very active proteolytic enzyme. A limitation of such protease application to steaks may be zones of overtenderized areas. Subsequent research should be done to isolate and purify the proteases and determine the minimal amount necessary to cause acceptable tenderization.

**Key Words:** *Calocybe gambosa*, beef tenderization, mushroom extract

**62 Effects of strip lion beef steaks dipped into trisodium phosphate incorporated into gelatin coating systems for cook loss, shear force and lipid characteritics.** L. M. McKenzie*, F. W. Pohlman, A. H. Brown Jr., P. N. Dias- Morse, L. N. Mehall, and T. N. Rojas, *University of Arkansas, Fayetteville*.

The objective of the study was to access the effects of trisodium phosphate (TSP) incorporated into gelatin coated systems in order to enhance tenderness and extend shelf life of strip loin steaks (n=126; 21 steaks/treatment). The steaks were allocated randomly to 1 of 6 treatments: 1) control (C); 2) 3% gelatin dip (3G); 3) Gel + 5 % TSP (G5T); 4) Gel + 10% TSP (G10T) 5) 5% TSP (5T) or 6) 10% TSP (10T). All of the strip loin beef steaks were placed under stimulated retail display until cooked to measure cook loss and to measure the strip loin shear force on days 0, 1, 3 and 7 of the study. In addition, the strip loin steaks were measured for lipid characteristics on days 0, 3 and 7. There was a treatment by day interaction ($P< 0.05$) for cook loss. In treatment (5T) on day 7 provided the highest ($P< 0.05$) for cook loss ($400.3 \pm 30.3$), while the lowest value for cook loss was treatment (G5T) on day 7 ($246.80 \pm 30.12$). However, there was no treatment by day interaction ($P > 0.05$) for lipid characteristics (TBARS) or shear force, throughout the study. The was a day effect ($P< 0.05$) for shear force. The shear force provided a higher value on day 0 ($2.49 \pm 0.10$) and day 3 provided the lowest ($1.48 \pm 0.08$). Therefore, the treatment of strip loin steaks with trisodium phosphate, gelatin or a combination of these, may have an effects on cooking loss and enhancing tenderness.

**Key Words:** trisodium phosphate, gelatin coating, strip loins

**63 Effects of bottom round beef steaks dipped into potassium lactate incorporated into gelatin coating systems for cook loss, sheer force, and lipid characteristics.** L. M. McKenzie*, F. W. Pohlman, L. N. Mehall, P. N. Dias- Morse, and T. N. Rojas, *University of Arkansas, Fayetteville*.

The effects of potassium Lactate (KL) incorporated into gelatin coated systems in order to enhance tenderness and extend shelf life of bottom round steaks (n=105; 21 steaks/treatment). The steaks were allocated randomly to 1 of 5 treatments: 1) control (C); 2) 3% gelatin dip (3G); 3) Gel + 1.5 % KL (GKL); 4) Gel + 3% KL (G3KL) or 5) 3% KL (3KL). All steaks were displayed under simulated retail conditions until cooked for cook loss and to measure the bottom round sheer force on 0, 1, 3 and 7 d of the study. In addition, the bottom rounds were measured for lipid characteristics on days 0, 3 and 7. There was a treatment and a day effect ($P< 0.05$) for both cook loss and shear force, however, there was no treatment by day interaction. Treatment (G3KL) had the highest cook loss (24.45 ± 1.99), while the (C) had the lowest cook loss (16.72. ± 1.99). There was a treatment by day interaction ($P< 0.05$) for TBARS throughout the study. Treatment (C) on day 7 provided the highest ($P> 0.05$) value for TBARS (.44 ± .08). Therefore, the treatment of bottom round steaks with potassium lactate, gelatin or a combination of these, may not have detrimental effects on tenderness and shelf life of bottom round steaks.

**Key Words:** potassium lactate, gelatin coating

**64 Instrumental color characteristics and summary of trained sensory color panel evaluation for color effects on strip loin beef steaks dipped into trisodium phosphate incorporated into gelatin coating systems.** L. M. McKenzie*, F. W. Pohlman, A. H. Brown Jr., P. N. Dias- Morse, L. N. Mehall, and T. N. Rojas, *University of Arkansas, Fayetteville*.

The objective was to access the effects of trisodium phosphate (TSP) incorporated into gelatin coated systems in order to extend the shelf life of strip loin steaks (n=126; 21 steaks/treatment). The steaks were allocated randomly to 1 of 6 treatments: 1) control (C); 2) 3% gelatin dip (3G); 3) Gel + 5 % TSP (G5T); 4) Gel + 10% TSP (G10T) 5) 5% TSP (5T) or 6) 10% TSP (10T). All steaks were placed under stimulated retail display conditions and were scanned for instrumental color characteristics and evaluated by sensory color panelists on 0, 1, 2, 3 and 7 d of the study. There was a treatment by day interaction ($P< 0.05$) for instrumental color for all parameters: L*(lightness), a*(redness), b*(yellowness), hue angle, and saturation index. Treatment (G5T) provided the highest value of a* (redness) on day 0 (28.22 ± 0.98). However, the most consistent treatment for color stability for a* (redness) throughout the study was 5T. There was a treatment by day interaction ($P<0.05$) for worst point color, overall color and percent discoloration across all treatments. In addition, treatment 5T provided the most consistent color stability for worst point color, overall color and percent discoloration. Therefore, the treatment of strip loin steaks with trisodium phosphate, gelatin or a combination of these may have an effect on instrumental color characteristic, improvement of shelf-life, and consumer acceptability.

**Key Words:** trisodium phosphate, gelatin coating, instrumental color

**65 Instrumental color characteristics and summary of trained sensory color panelists evaluation for color effects on bottom round beef steaks dipped into potassium lactate incorporated into gelatin coating systems.** L. M. McKenzie*, F. W. Pohlman, L. N. Mehall, P. N. Dias- Morse, and T. N. Rojas, *University of Arkansas, Fayetteville*.

The objective of the study was to access the effects of potassium lactate (KL) incorporated into gelatin coated systems in order to extend the shelf life of bottom round steaks (n=105; 21 steaks/treatment). The steaks were allocated randomly to 1 of 5 treatments: 1) control (C); 2) 3% gelatin dip (3G); 3) Gel + 1.5 % KL (GKL); 4) Gel + 3% KL (G3KL) or 5) 3% KL (3KL). All steaks were placed under stimulated retail display conditions and were scanned for instrumental color characteristics, and evaluated by a panel for color determination on 0, 1, 3 and 7 d of display. There was a treatment by day interaction ($P < 0.05$) for L* (lightness). The highest value of L* was treatment (3KL) on day 0 (51.09 ± 1.23). However, there was no treatment impact ($P > 0.05$) for a*(redness), b*(yellowness), hue angle, or saturation index. In addition, there was a treatment by day interaction ($P < 0.05$) for worst point color, overall color and percent discoloration across all treatments by the color panel. In treatment (G3KL) on day 4 the lowest value ($P < 0.05$) for overall color (1.29 ± 0.12). The treatment of bottom round steaks with potassium lactate, gelatin or a combination of these may not have detrimental effects on instrumental color characteristic, improvement of shelf- life, and consumer acceptability.

**Key Words:** potassium lacate, gelatin coating, instrumental color

**66 Tenderness and color of beef m. *biceps femoris* after marination with different acids.** J. Hinkle*, C. R. Calkins, A. S. de Mello Jr., L. S. Senaratne, and S. Pokharel, *University of Nebraska, Lincoln.*

Acid marination is known to improve meat tenderness. The objective of this study was to document the tenderness and color effects of marinating m. *biceps femoris* (30 bottom rounds, IMPS # 171) with low (0.1 M) and high (0.5 M) concentrations of lactic, acetic and sodium citrate dihydrate (food grade citric acid). Objective color measurements were taken at 0, 1, and 8 h after marination. Cooking loss and tenderness were analyzed from steaks cut at 0, 1, and 8 h and at 1, 3, 5, 7, 14, 21 and 28 days after injection. Samples were prepared by removing a control steak (0 h), injecting with the prepared solutions to 7% of initial weight, and tumbling for 30 min. Muscles were cut into steaks at 8 h and frozen at the times indicated after injection. Shear force measurements were obtained with an Instron and a Warner-Bratzler shear force attachment. Color was measured after bloom at 0, 1 and 8 h post-injection. Muscles marinated with 0.5 M sodium citrate dihydrate decreased in lightness (L*), whereas samples with 0.1 M lactic acid increased in L* at 1 h ($P \leq 0.05$). All muscles marinated with 0.1 M sodium citrate, acetic and lactic acid increased significantly in lightness at 8 h ($P \leq 0.05$). Both redness (a*) and yellowness (b*) decreased for all six treatment groups from 0 to 8 h ($P \leq 0.05$). Muscles marinated with 0.1 M lactic acid had the highest a* and b* values, whereas 0.5 M acetic acid had the lowest a* at 8 h. Acetic acid had higher cooking loss when compared to other acid treatments ($31.00^{A}$, $27.00^{B}$ and $21.00^{C}$, for acetic acid, sodium citrate dihydrate, and lactic acid respectively) ($P = 0.0001$). For tenderness, neither acid treatment, concentration nor the interaction between both main factors influenced WBSF values (7.00, 7.30, 5.60, 6.52, 7.14, and 7.20 for concentrations of high and low of acetic, citric, and lactic acids, respectively) ($P = 0.11$). Results of this work demonstrated that acid marination of m. *biceps femoris* using concentrations varying from 0.1 to 0.5 M of the three analyzed acids determined no effects on tenderness, minimal effects on color and cooking loss.

**Key Words:** beef, acid marination, *biceps femoris*

**67 Characterization of beef heel muscle under different cooking conditions.** S. Pokharel*, C. R. Calkins, A. S. de Mello Jr., L. S. Senaratne, and J. Hinkle, *University of Nebraska, Lincoln*.

This research was carried out to determine potential tenderness gradients within the lateral and medial portions of the beef heel (m. *gastrocnemius*) and also to characterize pH, water holding capacity, composition and color of the raw muscle. Out of 30 heels, 20 heels were divided into lateral (L) and medial (M) portions for oven roasting (OR =10L and 10M) and grilling (GR= 10L and 10M). The remaining 10 heels were cut into steaks (ST) containing both portions of the m. *gastrocnemius* (5 steaks/heel, whereas steak 1 = proximal and steak 5 = distal). Lab analyses were done with uncooked ST taken from the central region (steak 3). Oven roasting and grilling were cooked until L and M portions reach internal temperature of 69°C whereas ST were grilled to 70°C. All oven roasted and grilled L and M portions were divided in four steaks from the proximal to distal axis (steak 1 = proximal, steak 4 = distal) and cored for the measurement of tenderness by the Warner-Bratzler shear method. Objective color readings (L*, a*, and b*) were taken from every sample prior to cooking. The lateral and medial portions of GR were similar in shear force ($P$ = 0.98). No difference of shear force was observed for proximal and distal GR steaks ($P$ = 0.33). Lateral and medial portions of OR were also similar ($P$ = 0.34). However proximal and distal OR steaks were significantly different at $P$ = 0.04 ($4.65^{A}$, $4.19^{AB}$, $4.10^{B}$, and $3.93^{B}$ for steak 1, 2, 3, and 4, respectively). For ST, shear forces of lateral and medial areas were similar ($P$ = 0.41) whereas higher shear force was detected on the proximal end ($4.88^{A}$, $3.73^{B}$, $3.72^{B}$, $3.70^{B}$ from proximal to distal end, respectively) at $P$ = 0.006. The thickness of GR and OR increased during cooking for the medial side but decreased on the lateral side for oven roasted heels. Lateral portions of OR ($P$ = 0.001) and GR ($P$ = 0.003) had higher decreasing in length when compared to medial portions, likely due to connective tissue. No differences were observed on water holding capacity ($P$ = 0.83) and pH ($P$ = 0.22) comparing lateral and medial portions of ST. Lateral and medial portions did not differ in L* (lightness) and b*(yellowness). Medial portion was redder (higher a* values) than lateral ($P$ = 0.03). There were no differences for moisture ($P$ = 0.76), ash ($P$ = 0.57), and fat ($P$ = 0.46) contents between lateral and medial portions of the heel. There were few differences in tenderness or color of the lateral and medial sides of the m. *gastrocnemius*. Generally, the heel is less tender at the proximal end than the distal end.

**Key Words:** beef heel, *gastrocnemius*, tenderness

**68 Yield of ribeye, strip loin, and sirloin steaks from carcasses of varying weight groups and ribeye areas.** C. M. Leick* and J. M. Behrends, *Mississippi State University, Mississippi State*.

This study evaluated thickness and yield of ribeye, strip loin, and sirloin steaks cut to a uniform weight resulting from various carcass weights and ribeye areas. Carcasses (n=25) were selected from a commercial packing plant to represent five weight groups: 500 cwt (226.8 – 271.7 kg),

600 cwt (272.2 – 317.1 kg), 700 cwt (317.5 – 362.4 kg), 800 cwt (362.9 – 407.8 kg), and 900 cwt (408.2 – 453.1 kg). Carcasses were selected to have ribeye areas corresponding to carcass weight groups as follows: 500 cwt, 70.97 – 78.96 $cm^2$; 600 cwt, 78.71 – 85.81 $cm^2$; 700 cwt, 86.45 – 93.55 $cm^2$, 800 cwt, 94.19 – 101.29 $cm^2$, 900 cwt, 101.94 – 109.03 $cm^2$. All carcasses were yield grade 1 or 2, A maturity with a Small degree of marbling. Ribeye roll (IMPS 112A), strip loin (IMPS 180), and top butt (IMPS 184) subprimals were collected from each carcass. Each subprimal was cut by machine into steaks of uniform weight (345 g ribeye and strip loin; 284 g sirloin). Weight and thickness of each steak and weight of trim portions were recorded from the machine output and used to calculate total subprimal weight, total steak weight, total trim weight, and percent steak yield. Ribeye steak thickness ranged from 2.2 to 5.2 cm, strip loin steak thickness ranged from 2.8 to 4.8 cm, and sirloin steak thickness ranged from 2.1 to 5.8 cm. For all subprimals, average steak thickness and number of steaks increased ($P<0.0001$) with increasing carcass weight. Total subprimal weight and total weight of all steaks increased ($P<0.0001$) with increasing carcass weight, but trim weight was not different ($P>0.10$) among carcass weight groups for all subprimals. Percent ribeye steak yield was lower ($P=0.025$) for 500 cwt group carcasses compared to all other carcass weight groups, and percent sirloin steak yield tended to be lower ($P=0.064$) for 500 cwt group carcasses compared to 900 cwt group carcasses. Percent strip loin steak yield was not different ($P=0.461$) among carcass weight groups. Results may be used to select carcass weights and ribeye areas that will yield desired thicknesses of steaks cut to a specified weight. Additional research should be done to evaluate yields of steaks cut to different target weights and the use of those portions in foodservice settings.

**Key Words:** carcass weight, steak thickness, ribeye area

**69 Characterization of Revalor-XS on palatability characteristics of beef.** J. L. Igo*[1], J. C. Brooks[1], B. J. Johnson[1], J. Starkey[1], W. T. Nichols[2], J. P. Hutcheson[2], and M. F. Miller[1], [1]*Texas Tech University, Department of Animal and Food Sciences, Lubbock,* [2]*Intervet/Schering-Plough Animal Health, DeSoto, KS.*

Anabolic steroid implants are commonly used to increase growth performance and carcass leanness. The objective of this study was to determine the effects of various trenbolone acetate implants on Warner Bratzler shear force (WBSF) and consumer palatability scores for USDA Choice and Select quality grades of beef strip steaks aged for 14 and 21 d from cattle implanted prior to slaughter. Beef steers (n = 1600), subjected to the following treatments: 1) non-implanted short-fed (SF; 145 DOF); 2) non-implanted long-fed (LF; 170 DOF); 3) Revalor-IS on d-0 and Revalor-S on d-70 (IS/S); 4) Revalor-XS (RXS) on d-0, were randomly assigned to pens within blocks. Steaks measuring 2.54 cm thickness were fabricated and aged for 14 and 21 d postmortem. Average carcass marbling scores for the Choice and Select steaks, within each treatment, were RXS (550, 370), IS/S (530, 360), SF control (500, 360) and LF control (560, 360), respectively. Data analysis indicated USDA Select steaks from RXS cattle aged 14 and 21 d postmortem had lower ($P < 0.05$) WBSF than IS/S implanted cattle. Select steaks sampled after 21 d of aging indicated that RXS and non-implanted cattle had lower ($P < 0.05$) WBSF values than IS/S. WBSF did not differ among treatments from USDA Choice steaks aged 14 d. USDA Choice steaks aged 21 d from SF cattle had lower ($P < 0.05$) WBSF than LF. Consumer tenderness scores for USDA Choice 14-d aged RXS steaks were significantly lower than SF, but

similar to LF. However, there were no differences between RXS, SF and LF for overall and tenderness acceptability. Consumer flavor, juiciness and overall acceptability scores did not differ among treatment groups for Choice 14-d aged steaks. USDA Select, 14-d aged IS/S steaks had lower ($P < 0.05$) tenderness, tenderness acceptability, overall acceptability, and flavor scores than RXS, SF and LF steaks. Consumer tenderness scores for USDA Choice steaks aged 21 d from RXS and IS/S did not differ when compared to SF and LF. However, consumer tenderness ratings for USDA Select steaks aged 21 d from IS/S cattle were lower ($P < 0.05$) than RXS, SF and LF. Results indicate tenderness differences exist among implant treatments and RXS improves tenderness when compared to IS/S.

**Key Words:** consumer, palatability, trenbolone acetate

**70 Differences in beef tenderness associated with working chute behavior are not related to postmortem proteolysis.** J. D. Magolski*, E. P. Berg, V. L. Anderson, N. L. Hall, and K. R. Carlin, *North Dakota State University, Fargo*.

The objective of this experiment was to investigate if the association with chute behavior and exit velocity with beef tenderness is correlated to increases in postmortem proteolysis. Bos taurus-crossbred steers (n= 183) were blocked by BW (280 kg) in a randomized complete block design and allotted to 16 pens. Every 28 days, weights were obtained and measurements of temperament including exit velocity (EV), chute score (CS), and catch score (CAPS) were recorded. At 14 to 16 months of age (605 kg), steers were transported to a commercial slaughter facility. Approximately 7 cm of the longissimus thoracis muscle was removed and transported back to the NDSU laboratory for further analysis. At approximately 36 h and 7 d postmortem, 100 g samples were collected and analyzed for calpastatin activity, u-calpain autolysis and troponin-T degradation by western blotting and densitometry. Warner-Bratzler shear force (WBSF) was conducted on steaks aged to 14 d. Initial EV and average EV significantly correlated ($P < 0.05$) to WBSF (r= -0.1988 and r= -0.1447), respectively. WBSF was positively correlated ($P < 0.001$) to calpastatin activity at both 36 h and 7 d of aging (r= 0.4250 and r= 0.5961), respectively. At 36 h, the 80 kDa band of u-calpain positively correlated ($P < 0.0001$) to WBSF (r= 0.2890), while at 7 d, both the 80 kDa and 76 kDa bands exhibited no correlation ($P = 0.1030$ and $P = 0.5681$), respectively. Both 36-h and 7-d troponin-T intact bands significantly correlated ($P < 0.0001$) to WBSF (r= 0.3433 and r= 0.4860), respectively. The lower MW bands of troponin-T, indicating degradation, also correlated ($P < 0.0001$) to WBSF at 36 h (r= -0.3546) and 7 d (r= -0.4593). However, initial EV did not correlate to calpastatin activity at 36 h ($P = 0.8925$) or 7 d ($P = 0.5471$), 36-h intact troponin-T ($P = 0.6872$), 7-d intact troponin-T ($P = 0.2687$), 36-h u-calpain autolysis ($P = 0.4223$) or 7-d u-calpain autolysis ($P = 0.1944$). Average EV also did not correlate to 36-h calpastatin activity ($P = 0.6879$), 7-d calpastatin activity ($P = 0.3418$), or u-calpain autolysis at 36 h ($P = 0.1286$) or 7 d ($P = 0.5004$). However, average EV showed a tendency to correlate with 36-h intact troponin-T ($P = 0.0767$), and was significantly correlated ($P = 0.0272$) to 7-d intact troponin-T (r= -0.1671). Furthermore, a linear decrease in 7-d intact troponin-T was observed with decreasing average EV score ($P = 0.0414$). Steers exhibiting a fast average EV (< 0.70 sec) had more intact troponin-T (0.819 ± 0.044) than both the moderate (0.754 ± 0.035) and slow EV (0.701 ± 0.036) steers. These data indicate that postmortem proteolysis was significantly correlated to WBSF, and a linear contrast between

troponin-T degradation and average exit velocity exist, however, chute behavior does not serve as an indicator of these same protein measurements.

**Key Words:** beef, temperament, exit velocity

**71 Dietary protein levels in feedlot diets altered adipose deposition and plasma urea nitrogen with little influence on plasma glucose and insulin.** T. J. Machado*, D. M. Wulf, and R. H. Pritchard, *South Dakota State University*, *Brookings*.

The objective of this study was to determine whether the altered adipose deposition, due to dietary protein levels, was explained by plasma urea nitrogen, glucose and insulin levels. Ninety-six Angus-cross and 96 Limousin-cross steers were used in two separate feeding periods. Within each breed type, the steers were assigned to twelve pens, eight head per pen with three pens randomly assigned to one of four treatments. Treatments utilized two dietary crude protein levels (CP), Low (11.7% ± 0.5) and High (15.5% ± 0.6), delivered during two feeding phases, First Half (FH) and Second Half (SH). The change from FH to SH occurred when the steers reached 56% and 54% of their total weight gain for Angus-cross and Limousin-cross, respectively. The four treatments are as follows: 1) Low FH, Low SH (Lo-Lo); 2) Low FH, High SH (Lo-Hi); 3) High FH, Low SH (Hi-Lo); 4) High FH, High SH (Hi-Hi). Blood samples were collected at the time of diet change, one week after diet change, and one week prior to harvest. Blood samples were collected prior to first daily feeding. Steers receiving the High CP during the FH had higher average daily gains and dry matter intakes ($P < 0.05$) than the steers receiving Low CP, but when analyzed over the entire feeding period only dry matter intake was higher for the Hi-Hi steers ($P < 0.05$) compared to all other treatments. There was no difference between treatments for marbling score ($P > 0.05$). Steers from the Hi-Hi had higher adjusted fat thickness (Hi-Hi 1.56 cm, Hi-Lo 1.26 cm, Lo-Hi 1.32 cm, Lo-Lo 1.30 cm), and percentage of kidney, pelvic and heart fat (Hi-Hi 2.80, Hi-Lo 2.55, Lo-Hi 2.59, Lo-Lo 2.38) than the other treatments ($P < 0.05$). For all three bleeding periods the steers that were receiving the high CP diet had higher plasma urea nitrogen (PUN) compared to the low CP diet steers ($P < 0.05$). Limousin-cross steers had a lower PUN concentration at the time of diet change (9.45 mg/dl vs 10.65 mg/dl) and a higher concentration prior to harvest (12.31 mg/dl vs 11.48 mg/dl) compared to Angus-cross ($P < 0.05$). There were no significant differences amongst treatments for glucose and insulin ($P > 0.05$). Limousin-cross steers had lower glucose (82.95 mg/dl vs 85.79 mg/dl) at time of diet change and higher glucose (83.58 mg/dl vs 79.65 mg/dl) prior to harvest than Angus-cross ($P < 0.05$). Limousin-cross steers also had higher insulin one week after diet change (1.78 ng/ml vs 1.42 ng/ml) than Angus-cross ($P < 0.05$). The dietary treatments altered insulin levels differently for each breed prior to harvest with the Lo-Lo diets resulting in the highest (2.32 ng/ml) for the Limousin-cross steers and the lowest (1.52 ng/ml) for the Angus-cross steers. Limousin-cross Lo-Lo was higher (2.32 ng/ml) than Limousin-cross Lo-Hi (1.62 ng/ml), and Angus-cross Lo-Lo (1.52 ng/ml) was lower than the Angus-cross Lo-Hi (2.07 ng/ml) ($P < 0.05$). In conclusion, timed protein restrictions did not alter marbling; however, the steers fed the greatest amount of CP over the total period deposited proportionally the most fat into subcutaneous and internal depots than into intramuscular depots. Dietary CP level altered PUN with little impact on plasma glucose and insulin.

**Key Words:** dietary protein, marbling, adipose

**72 Effects of zilpaterol hydrochloride and zilpaterol hydrochloride withdrawal time on beef carcass cutability, composition, and tenderness.** J. N. Shook*[1], D. L. VanOverbeke[1], L. A. Kinman[1], C. R. Krehbiel[1], B. P. Holland[1], M. N. Streeter[2], D. A. Yates[2], and G. G. Hilton[1], [1]*Oklahoma State University, Stillwater*, [2]*Intervet/Schering Plough, Inc., Millsboro, DE.*

The impact of zilpaterol hydrochloride (ZH) on carcass yield, composition, and tenderness was evaluated using a subset (n = 128) selected from three hundred eighty four (BW = 356 ± 23.3 kg) British and British × Continental steers. Steers were separated into two weight blocks and randomly assigned to pens (32 pens per block; 6 steers/pen) using a computer generated schedule. Main effects were the addition of 0 or 8.3 mg/kg ZH for the final 20 d of feeding and each inclusion level was paired with withdrawal periods of 3, 10, 17, or 24 d. The two animals with weights closest to the pen average were selected for carcass fabrication to determine carcass yield, composition, and tenderness. The carcasses from animals fed ZH had greater (P = 0.008) individual side weights. Carcass fat determinations were unchanged (P = 0.70) by ZH. Weights of the strip loin (P = 0.01), peeled tenderloin (P = 0.02), and top sirloin butt (P < 0.001) were all improved with ZH. When expressed as a proportion of carcass weight, ZH increased percentage of carcass in the top sirloin butt (P = 0.006), bottom sirloin tri-tip (P = 0.02), top inside round (P = 0.002), bottom round flat (P = 0.001), and flank steak (P = 0.02). A longer withdrawal time (WT) increased (P < 0.001) carcass weights. Shoulder clod weights were greatest (P < 0.001) with 17 d WT from ZH, while chuck roll weights were greatest (P = 0.02) at 17 and 24 d of WT. Peeled tenderloins, top sirloin butts, and eye of rounds responded to WT, with increased (P < 0.001) weights seen at 10 d of WT as compared to all other WTs. Shear force values were higher at each of the 3 aging times, 7 d (P < 0.001), 14 d (P < 0.001), and 21 d (P = 0.003), in steaks from ZH fed steers compared to control steers. Protein percentages were greater in ZH steaks (P = 0.03) and ZH ground beef trim (P < 0.001). Percent moisture was increased (P < 0.001) in strip loin steaks at 3 and 10 d WT. Ground beef trim had an increase (P = 0.04) in percent moisture and a decrease (P = 0.01) in percent fat at 10 d WT. Carcass weights and yields were improved with ZH feeding and may continue to improve even up to 10 d after withdrawal of the supplement. Tenderness was slightly reduced with ZH supplementation but was unaffected by WT. Zilpaterol hydrochloride can be a valuable supplement to finishing beef steers to improve carcass lean yields and composition.

**Key Words:** beef, zilpaterol withdrawal, cutability

**73 Evaluating effects of Zinpro Performance minerals® on performance and carcass characteristics of steers fed finishing diets designed for natural beef production.** C. L. Coggins*[1], D. L. VanOverbeke[1], B. P. Holland[1], C. R. Krehbiel[1], C. K. Larson[2], and J. B. Morgan[1], [1]*Oklahoma State University, Stillwater*, [2]*Zinpro Corporation, Eden Prarie, MN.*

Eighty steers, (harvest group 1, n = 42 and harvest group 2, n = 38, respectively) were used to evaluate the effect of organic Zinpro Performance Minerals® on carcass characteristics, tenderness and meat color. Steers were blocked by initial weight and assigned one of two

treatment groups, inorganic (IG) or organic (OG) trace mineral supplements, at weaning. Strip loins were collected upon harvest and aged for 14 d. Carcass characteristics, retail-case life, Warner-Bratzler shear force (WBS), and trace mineral content were evaluated. No differences ($P > 0.10$) were found between treatment groups for WBS and cooking loss percentage. In harvest group one, IG had significantly ($P < 0.05$) higher hot carcass weights (HCW) than OG and tended to have more backfat ($P = 0.07$). Kidney, pelvic and heart fat percentage (KPH) tended to be lower ($P = 0.07$) in IG compared to OG. No differences ($P > 0.10$) were found for liver condemnation percentages. No differences ($P > 0.10$) were found for the subjective color evaluation between the two treatments. Furthermore, no differences ($P > 0.10$) were observed between treatments for a* and b* values. Steers in IG initial harvest group had higher ($P < 0.05$) L* values than the organic contemporaries. Trace mineral analysis revealed no differences ($P > 0.10$) between treatments for calcium, sodium, iron, copper, or manganese content. In harvest group one, zinc content tended to be higher ($P = 0.07$) and nickel was higher ($P < 0.05$) in IG. For harvest group two, sulfur, magnesium, potassium and phosphorus were higher ($P < 0.05$) for IG compared to OG. Supplementing with an organic source of trace minerals will allow cattle to qualify for organic or natural beef production without any negative effects on carcass quality or tenderness. Other supplements such as vitamin E may be added to improve lean muscle color and extend retail-case life.

**Key Words:** trace minerals, tenderness, lean color

**74 Influence of anabolic growth implants on feedlot cattle possessing high genetic potential for enhanced palatability attributes.** J. C. Galbreath*, R. J. Maddock, G. P. Lardy, V. L. Anderson, B. R. Ilse, C. S. Schauer, N. L. Hall, and E. P. Berg, *North Dakota State University, Fargo.*

The objective of this study was to determine if administration of anabolic growth implants to feedlot finished beef cattle influences carcass attributes of cattle genetically indexed for enhanced beef palatability. Growth performance and carcass data were collected for 77 Angus-sired calves assigned to two treatment groups during the finishing period. Cattle in Treatment 1 (IM 17 steers, 22 heifers) received an implant containing 100 mg trenbolone acetate and 14 mg estradiol benzoate (Synovex Choice, Wyeth Animal Health) at weaning and again during the finishing period. Controls (NOIM 19 steers, 19 heifers) received no implant at any time. Weights were recorded on arrival and every 42 d until harvest. Tissue samples were collected for commercial IGENITY (Merial Ltd.) genetic profile indexing for carcass traits that included tenderness and percent USDA Choice. Cattle were fed to a common end weight (500 kg) and harvested on two dates. Carcass measurements were collected 24 h postmortem. Longissimus samples were collected at the 12th rib for Warner-Bratzler shear force (WBS) which was measured 16 d postmortem. Average daily gain and hot carcass weight (HCW) were greater for the IM treatment ($P < 0.01$). No differences ($P > 0.05$) were observed for ribeye area, fat thickness, KPH, yield grade, marbling, or WBS between IM and NOIM treatments. Least squares means separation in a general linear model was used to determine treatment effect on WBS and marbling relative to genetic potential for tenderness, marbling, and percent choice respectively. IGENITY results for cattle were sorted into low, medium, and high potential for each trait tested. No differences ($P > 0.05$) were observed among cattle indexing high (IGENITY

tenderness 8-10) across IM/NOIM. Cattle indexing high for percent choice had higher marbling scores than medium ($P < 0.01$) and low ($P < 0.05$) indexing cattle. The trends observed in this study suggest that anabolic implant use did not hinder genetic potential for tenderness, percent choice, or marbling. Future research is necessary utilizing a larger sample size with greater genetic diversity.

**Key Words:** beef, anabolic growth implant, genetic profile

**75 Effects of glycerol level in feedlot finishing diets on beef carcass quality.** T. M. Jeske*, V. L. Anderson, B. R. Ilse, R. J. Maddock, and E. P. Berg, *North Dakota State University, Fargo.*

This study investigated the effects of glycerol in finishing rations on beef carcass traits and tenderness. Yearling heifers (n = 131) were purchased from a commercial source and were sorted into 16 identical pens by weight (411.03 ± 15.03 kg) in a randomized complete block design. Treatments of 0, 6, 12 and 18 percent glycerol (DM Basis), with four pens per treatment, replaced dry rolled corn and co-products in finishing diets (62 Mcal NEg/cwt). Diets met or exceeded NRC requirements for crude protein. Heifers were fed for 102 days and shipped to a commercial abattoir. Ribeye area, fat thickness over the 12th rib, KPH, marbling score, and HCW were measured to calculate USDA Yield grade and Quality grades. A 7.6-cm portion of the short loin was obtained from each carcass and cut into two steaks upon arrival at the NDSU meat lab. Minolta color readings and pH were taken from individual steaks. Steaks were then vacuum packaged and aged for 14 days at 4°C when Warner Bratzler shear force was conducted on all 131 steaks and percent cook loss was calculated. Amount of glycerol in the finishing diets did not affect carcass traits as hot carcass weight, external fat, kidney, pelvic and heart fat, marbling and USDA Quality and Yield Grades ($P > 0.10$) were similar among treatments. Meat quality traits were not affected by glycerol in the finishing diet as Minolta color readings, pH value, Warner Bratzler shear force and cooking loss of steaks were similar ($P > 0.10$) among treatments. This study indicated that glycerol can replace up to 18% of dry rolled corn in beef cattle finishing diets without altering carcass and meat quality.

**Key Words:** beef, glycerol, carcass

**76 Effects of distiller's grain and direct fed microbial (10-G) on carcass characteristics in finishing beef steers.** F. F. Korthaus*[1], E. S. Vanzant[1], G. Rentfrow[1], K. K. Kreikemeier[2], D. L. Harmon[1], and K. R. McLeod[1], [1]*University of Kentucky, Lexington,* [2]*Vit-E-Men, Norfolk, NE.*

In a 112 day finishing study, 192 crossbred steers (initial BW 394 ± 1.2kg) were used to evaluate the effects of modified corn distiller's grain (MDG) and a direct fed microbial (DFM; Life Products 10G, a proprietary formulation of five different strains of lactic acid bacteria). Steers were assigned within weight blocks, to 6 treatments in a 3×2 factorial arrangement and fed in pens of 4. Treatments included 0, 20 or 40% (DM basis) of MDG with or without DFM provided at 10g• $hd^{-1}$• $d^{-1}$. The diet DM was comprised of 5% corn silage, 5% alfalfa haylage, 10% supplement and 80% concentrate comprised of varying quantities of MDG, cracked corn and

high moisture corn. The 0 and 20% MDG diets contained 14.2% CP and the 40% MDG diet contained 18.6% CP. Body weight measurements were taken on d 0, 1, 28, 56, 84, 111 and 112. Steers were harvested on d 113 and carcass data was collected. Loin samples were taken from 37 steers and analyzed for fat, moisture, ash and CP %, Warner Bratzler shear force (WBSF), objective color (L*, a*, b*, hue angle and chroma), and sensory characteristics. Fourty eight hours after harvest, objective color measures were taken (L*, a* and b* values) from three locations on each steak and averaged using a Hunter Miniscan Colorimeter (D65/10°). Steaks were vacuumed packaged and stored at 4°C for 14 d, after which time they were frozen at -10°C until WBSF and taste panel was performed. Steaks were then cooked to internal temperature of 70°C in a clam shell cooker and served warm to a sensory panel. The eight member panel was asked to evaluated tenderness, juiciness and off-flavor under red light on a 15 cm line scale. There were no interactions between the level of MDG and DFM ($P \geq .07$). Increasing level of MDG resulted in linear decreases in L* value ($P = .04$; 40.0, 39.2 and 38.1 for 0, 20 and 40% MDG) and hue angle calculations ($P = 0.07$; 41.5, 40.9 and 40.3 for 0, 20 and 40% MDG). Steers fed DFM had greater HCW ($P= .02$; 369 vs 378 ± 2.6kg), and ribeye area ($P = .08$; 83.7 vs 85.6cm). Steak samples from steers fed DFM had a greater WBSF ($P = .05$; 4.4 vs 5.1 kg), but these differences were not detected by the sensory panel ($P = .39$; tenderness = 6.0 vs 6.5). Furthermore, the addition of MDG or DFM to the diet did not affect sensory panel juiciness or off-flavor intensity ($P \geq .27$), as well as fat, moisture, ash or CP ($P \geq .13$). Modified corn distiller's grain and DFM had limited impact on beef color and subjective and objective sensory attributes.

**Key Words:** distiller’ s grain, DFM, carcass traits

**77 Effects of vitamin E supplementation on color stability of beef from steers fed wet distillers grains plus solubles.** A. S. de Mello Jr.*, C. R. Calkins, T. Carr, and G. E. Erickson, *University of Nebraska, Lincoln*.

Surface discoloration of beef leads to revenue losses due to lower shelf life and reduced consumer desirability. Our previous research showed that feeding wet distillers grains plus solubles (WDGS) increased polyunsaturated fatty acids (PUFA) in beef, which led to higher oxidation, lower color stability, and off-flavor development. Two experiments were conducted to verify the effects of vitamin E supplementation on fatty acid profile and color of beef from steers fed WDGS. In experiment 1, steers (n = 32) were allocated to 4 feeding treatments containing WDGS and 500 I.U. of vitamin E/head/d. Animals were fed diets containing corn, corn + vit. E, 40% WDGS, or 40% WDGS + vit. E for 100 d. After 7 d of aging, m. *teres major* (TER) and m. *infraspinatus* (INF) were analyzed for fatty acid profile. Feeding diets containing 40% WDGS increased 18:1 trans ($P < 0.0001$), PUFA ($P = 0.0008$), and Omega 6 fatty acids ($P = 0.0008$) of TER when compared to corn-based diets. Similar results were observed for INF when feeding WDGS ($P = 0.05$, $P < 0.0001$, and $P < 0.0001$, for 18:1 trans, PUFA, and Omega 6 fatty acids, respectively). Vitamin E supplementation did not alter fatty acid profile of lean from either muscle. In experiment 2, ninety steers were randomized in 6 dietary treatments. Animals were fed 128 d one of five treatments containing 35% of WDGS (DM-basis) plus different levels of vitamin E (**0E, 100E, 300E, 500E**, or **1000E** I.U. daily.) or a control corn-based (**CORN**) dietary treatment with no vitamin E to verify beef surface discoloration (%). M. *longissimus dorsi* (LD)

(n = 180) were collected and aged for 7 (n = 90) and 21 d (n = 90). Three steaks were cut from each LD and displayed for 4 days under permeable film, high $O_2$ (80 - 85% $O_2$), and low $O_2$ (0 - 382 ppm O2) packaging atmospheres. Steaks packaged under low $O_2$ were 100% discolored on the first day of retail display, independent of dietary treatment and aging period. Steaks from treatments **CORN, 100E, 300E** and **1000E** aged 7 d and displayed under permeable film had less discoloration at the end of the display period ($P \leq 0.05$) when compared to **500 E**, whereas steaks from all treatments displayed under high $O_2$ were similar in color stability after the display period ($P > 0.05$). When permeable film packaged, 21-d aged steaks from treatment **1000E** had the least discoloration (7.87) of steaks from all other treatments (**CORN** = 14.51, **0E** = 17.96, **100E** = 14.24, **300E** = 15.51, and **500E** = 14.18) ($P \leq 0.05$). In contrast, high $O_2$ packaging kept discoloration low in the **CORN** treatment and all vitamin E treatments (**CORN** = 0.51, **100E** = 0.49, **300E** = 0.18, **500E** = 0.18, and **1000E** = 0.17). The **0E** treatment had the most discoloration after 4 d of display (**0E** = 12.40) ($P \leq 0.05$). This work reaffirmed that feeding WDGS, with or without vitamin E, increases PUFA. However, supplementation with 1000 I.U. of vitamin E daily during the feeding period mitigates color defects when beef is moderately aged and displayed under permeable film packaging. Modified atmosphere packaging containing high $O_2$ also provides color stability when associated with any level of vitamin E supplementation.

**Key Words:** beef color, distillers grains, vitamin E

**78 Vitamin E supplementation mitigates the boost in lipid oxidation and its secondary effects on beef quality due to wet distillers grains feeding.** L. S. Senaratne*, C. R. Calkins, and A. S. de Mello Jr., *University of Nebraska, Lincoln.*

Effects of feeding wet distillers grains (WDG), distillers solubles (DS), and vitamin E (E) supplementation on fatty acid composition, lipid oxidation, color stability, and sensory attributes after cooking of short-term and long-term aged beef strip loin (*M. longissimus lumborum*) were investigated. Crossbred yearlings (n = 90) were randomly assigned to one of ten diets contained 0, 20, or 40% (DM basis) of WDG with or without vitamin E (E; 500 IU of α-tocopherol acetate/steer daily for 100 d) and DS (0 or 30% by wt of WDG). Strip loins were aged for 7 and 28 d postmortem at 0 to 2°C and cut into 2.54 cm thick steaks. Aerobically packaged 7 and 28 d aged strip loin steaks were displayed for 7 d under simulated retail display conditions. Fatty acid composition of strip loins from all diets was analyzed by gas chromatography. Percentage surface discoloration was subjectively evaluated by a trained panel during retail display period. Oxidation status of steaks displayed for 0, 4 and 7 d were tested by measuring accumulation of thiobabituric acid reactive substances (TBARS). Steaks were grilled to an internal temperature of 71°C and presented to a trained sensory panel (8 panelists) to evaluate tenderness, juiciness, connective tissue content and off-flavor intensity based on 8-point hedonic scales. Panelists evaluated presence or absence of off-flavors of steaks. When comparing WDG+DS+E (WDGS plus E) and control diets, feeding WDGS plus E diets significantly increased polyunsaturated fatty acids (PUFA), trans, omega 6, omega 6:omega 3 and PUFA:SFA fatty acids . Vitamin E supplementation reduced oxidation of 7 and 28 d aged strip loin steaks ($P \leq 0.05$). Long-term aging significantly increased the TBARS over short-term aging. Inclusion of dietary WDG at 20% or 40% elevated lipid oxidation in strip loins over corn diets, regardless of aging period ($P \leq$

0.05). Diets containing DS reduced TBARS of both muscles during retail display ($P \leq 0.05$). The greatest negative effects on discoloration of strip steaks occurred due to aging, followed by the presence of DS and then by the levels of WDG ($P \leq 0.05$). As discoloration of strip steaks increased, the importance of vitamin E in reducing discoloration also increased ($P \leq 0.05$). The results demonstrated that vitamin E supplementation of cattle can be used as a strategy to minimize the losses associated with beef during retail display due to WDG and DS feeding.

**Key Words:** beef, wet distillers grains, vitamin E

**79 Effects of feeding dried distillers grains with solubles and glycerol on pork loin quality.** A. N. Gipe*[1], T. A. Houser[1], A. W. Duttlinger[1], M. D. Tokach[1], S. S. Dritz[1], J. M. DeRouchey[1], J. L. Nelssen[1], R. D. Goodband[1], M. C. Hunt[1], K. J. Prusa[2], C. A. Fedler[2], and C. R. Raines[3], [1]*Kansas State University, Manhattan,* [2]*Iowa State University, Ames,* [3]*The Pennsylvania State University, University Park.*

Seventy-seven barrows (PIC, initial BW = 31 kg) were used to evaluate the influence of feeding dried distillers grains with solubles (DDGS) and glycerol for 70-d on pork loin quality attributes. Pigs were blocked by BW and randomly assigned to one of six dietary treatments ($n$ = 7 replications each). Pigs were fed corn-soybean meal based diets with added DDGS or glycerol. The experiment had a 2 × 3 factorial design with main effects of feeding DDGS (0 or 20%) and glycerol (0, 2.5 or 5%). Loins from the left side of the carcass were removed 24 h postmortem, vacuum packaged, and stored at 4°C. At 10-d postmortem, loins were weighed, removed from vacuum packaging, blotted dry, and reweighed to determine percentage of purge loss. Seven 2.54-cm thick center-cut loin chops were utilized for analysis of percentages of drip and cooking losses, pH, instrumental color (L*a*b*), visual color, marbling score, WBSF, fatty acid profile, and trained sensory panels. Trained sensory panelists ($n$ = 7) evaluated center-cut loin chops for myofibrillar tenderness, overall tenderness, connective tissue amount, juiciness, pork flavor and off-flavor intensity. There were no DDGS × glycerol interactions nor main effect differences ($P$ > 0.05) for percentages of purge loss, drip loss, and cooking loss, pH, instrumental color (a*b*), visual color, and marbling score. Loin chops from pigs fed 5% glycerol were lighter ($P$ < 0.05, higher L* value) than loin chops from pigs fed 2.5% glycerol, and loin chops from pigs fed 0% glycerol had intermediate L* values. Loin chops from pigs fed diets with 20% DDGS had higher ($P$ < 0.05; less tender chops) WBSF values than chops from pigs fed 0% DDGS. Sensory myofibrillar tenderness, connective tissue amount, and overall tenderness scores for chops from pigs fed 20% DDGS were lower ($P$ < 0.05; less tender chops) than chops from pigs fed diets with 0% DDGS. Loin chops from pigs fed 20% DDGS without added glycerol had more ($P$ < 0.05) off-flavors than all other treatments. There were no differences ($P$ > 0.05) among treatments for sensory juiciness and pork flavor intensity scores. Loin chop samples from pigs fed 20% DDGS had more ($P$ < 0.05) linoleic acid (C18:2n6) and eicosadienoic acid (C20:2), and higher calculated iodine values than loin samples from pigs fed 0% DDGS. There was less ($P$ < 0.05) palmitoleic acid in loins from pigs fed 20% DDGS than those from pigs fed 0% DDGS. Feeding pigs 20% DDGS resulted in less tender chops with more off-flavors than pigs fed 0% DDGS; however, the inclusion of dietary glycerol decreased off-flavor intensity in pork chops. Feeding pigs 20% DDGS increased polyunsaturated fatty acids and calculated iodine values in loins compared with feeding pigs 0% DDGS, which indicates that the fat from these pigs is

softer. Pork producers with growing and finishing operations can make effective use of economical by-products from the ethanol and biodiesel industries with minimal or no reduction in pork loin quality at levels tested.

**Key Words:** DDGS, glycerol, pork quality

**80 Effects of distillers dried grains with solubles on belly/bacon quality.** K. M. McClelland*, G. A. Anderson, R. B. Cox, G. L. Cromwell, M. D. Lindemann, and G. Rentfrow, *University of Kentucky, Lexington*.

Pricing and market availability have led many producers to seek alternative feedstuffs such as distillers dried grains with solubles (DDGS). The objective of this study was to evaluate the bacon quality of pigs fed varying levels of DDGS. Crossbred pigs (barrows/gilts; n = 60) averaging 34 kg body weight were randomly allotted to one of four treatment groups and fed corn-soybean meal diets with 0, 15, 30, or 45% DDGS. When the mean pen weight reached 120 kg, pigs were humanely harvested at the University of Kentucky Meats Laboratory. Bellies were removed according to IMPS 408 specifications 24 hours post mortem. Lateral and vertical flex tests were performed to determine belly firmness. A higher lateral and a lower vertical flex indicate a firmer belly. Bellies were transported to a commercial facility, weighed prior to pumping, and pumped to target 12% retention, then re-weighed to determine actual pumping percentage. After enhancement, bellies were cooked according to a commercial protocol and then weighed to determine smokehouse yield. Bacon slabs were pressed then sliced at nine slices per 2.54 cm by a high speed slicer, and incomplete slices were removed to determine slicing yield. Slabs containing complete slices were divided into five equal sections. The first two slices from each section were removed for fracture analysis and the following two slices were used for cooking evaluation. These slices were cooked on a 157° C surface to target ≤ 40% of the original weight to determine cook loss. Distortion (curling during cooking) was determined on a 1 to 5 scale (1 = no distortion; 5 = severe distortion). Pigs fed 0% DDGS had firmer bellies than those fed DDGS ($P = 0.028$). Shatter of bacon slices decreased with the addition of DDGS in the diet ($P = 0.036$). Bacon from pigs that received 0% DDGS had increased distortion scores as compared with pigs that received 15% DDGS ($P = 0.073$). No differences were observed across treatments for percentage pump retention, smokehouse yield, slicing yield, or cook loss ($P > 0.10$). Based on results from this study, the addition of DDGS to a finishing diet decreases the belly firmness, while having a limited impact on the quality characteristics of sliced bacon.

**Key Words:** bacon, distillers dried grains, belly quality

**81 Dietary inclusion of dried distillers grains with solubles (DDGS) up to 45% does not change pig growth performance or carcass traits but increases iodine values to unacceptable levels.** D. Pompeu*, B. R. Wiegand, M. Carlson-Shannon, J. W. Rickard, K. S. Roberts, H. L. Evans, and S. Turner, *University of Missouri, Columbia*.

An experiment was performed to evaluate the effects of dietary levels of DDGS added to a corn-soybean meal diets on growth performance, carcass characteristics and fatty acid profiles of both

belly and jowl depots for growing-finishing pigs. The experiment was performed in three phases: from 33 to 60 kg, from 61 to 91 kg and from 92 to 121 kg BW. A total number of 64 crossbred pigs were used with a total of 4 replications of 4 animals per pen. Pen was the experimental unit. Four different diets were formulated to contain 0, 15, 30 and 45% DDGS. The level of true ileal digestible (TID) lysine was adjusted for each phase being 0.83, 0.70 and 0.58%, respectively. Carcasses were sampled for jowl fat (anterior tip) and belly fat (posterior to sternum and anterior to teat line). No differences were found (P>0.15) for growth performance among treatments for all the parameters analyzed (ADG, ADFI and FE). Regarding the carcass and meat quality traits analyzed, no differences were found (P>0.14) for any item (hot carcass weight, tenth rib back fat, last rib back fat, loin eye area, dressing percentage and Minolta L, a and b values). Fatty acid methyl esters as analyzed by gas chromatography revealed a decrease with increasing DDGS (P < 0.0001) in 16:0 and 18:0 with ranges from 25.31% to 21.67% and 11.89% to 9.11%, respectively for belly samples. Also, 16:1 and 18:1n9c decreased with increasing DDGS (P < 0.0004) with ranges from 2.67% to 1.86% and 41.30% to 35.53%, respectively. In contrast, 18:2 and 20:2 increased with increasing DDGS (P < 0.0001) with ranges from 11.93% to 25.64% and 0.45% to 0.82%, respectively. Subsequently, iodine value increased with increasing DDGS (P < 0.0001) with values of 59.64, 64.73, 70.40, and 77.82 for 0, 15, 30, and 45% DDGS, respectively. Analysis of jowl samples showed a decrease with increasing DDGS (P < 0.0012) in 16:0 and 18:0 with ranges from 24.39% to 20.76% and 10.45% to 8.48%, respectively. Also, 16:1 and 18:1n9c decreased with increasing DDGS (P < 0.0096) with ranges from 2.77% to 2.10% and 43.63% to 36.97%, respectively. In contrast, 18:2 and 20:2 increased with increasing DDGS (P < 0.0001) with ranges from 11.69% to 22.92% and 0.53% to 0.96%, respectively. Subsequently, iodine value increased with increasing DDGS (P < 0.0001) with values of 60.70, 64.23, 68.75, and 73.90 for 0, 15, 30, and 45% DDGS, respectively. These results indicate that DDGS can be fed up to 45% in the grow-finish diet for pigs without negatively changing growth or carcass characteristics. However, dietary inclusion of DDGS above 30% results in IV greater than 70 which could be detrimental to fat quality in pork bellies. This decrease in fat saturation can alter processing characteristics of pork bellies used in bacon manufacture and have the potential for greater oxidative rancidity of fat.

**Key Words:** DDGS, pork, iodine value

**82 The effect of conjugated linoleic acid and arginine supplementation to pigs on the growth performance, carcass traits, meat quality, lipogenesis in vitro, and fatty acid composition.** G. Go*, G. Wu, and S. B. Smith, *Texas A&M University, College Station.*

We hypothesized that the combination of dietary conjugated linoleic acid (CLA) plus arginine would increase lean mass and depress adiposity in market weight pigs. Eight pigs (80 kg) were assigned to four groups in a 2 x 2 factorial design, differing in fatty acid and amino acid supplementation (control: 2.05% alanine + 1% canola oil; CLA: 2.05% alanine + 1% CLA (mixed isomers); arginine: 1% arginine + 1% canola oil; arginine + CLA: 1% arginine + 1% CLA). The pigs were fed individually for 5 wk. Preliminary tests indicated that up to 2% arginine and 1% CLA supplementation is acceptable without interfering with lysine absorption. There were no significant differences across treatments in growth performance, including daily feed intake and daily weight gain. Neither arginine nor CLA supplementations enhanced carcass

traits or meat quality characteristics including loin area, back fat thickness, pH45min, pH24hr, or water holding capacity. However, pork from the CLA group had increased lightness (L*) and the arginine group had increased redness (a*) ($P < 0.05$). Lipogenesis in vitro using glucose and palmitate was measured in liver, longissimus muscle, abdominal fat, and subcutaneous fat. All treatments decreased the rate of conversion from glucose to triacylglycerol in liver ($P < 0.05$), but increased palmitate conversion to lipid. The lipogenesis from palmitate increased in longissimus muscle in the CLA group ($P < 0.05$). There were no significant treatment differences in lipogenesis in either adipose tissue depot. Major fatty acids including oleic acid, linoleic acid, and arachidonic acid were not affected by dietary CLA or arginine supplementation in tissues and plasma. In addition, the MUFA:SFA ratio and SCD ratio (16:1/18:0) were not significantly affected by CLA or arginine. In conclusion, dietary CLA and arginine supplementation to pigs did not cause significant differences in adiposity or meat quality.

**Key Words:** conjugated linoleic acid (CLA), arginine, adiposity

**83 Dietary inclusion of conjugated linoleic acid (CLA) changes fatty acid profile and certain processing characteristics of injected and tumbled bacon.** B. R. Wiegand[1], K. S. Roberts*[1], H. L. Evans[1], R. B. Hinson[1], B. Cousins[2], and G. L. Allee[1], [1]*University of Missouri, Columbia*, [2]*BASF Corporation, Florham Park, NJ*.

Soft fat can negatively influence the handling and processing characteristics of pork bellies and the subsequent shelf stability of bacon products. Soft fat in pork is usually a function of feeding highly unsaturated sources of dietary fat. Literature reports indicate that feeding conjugated linoleic acid (CLA) will shift the fatty acid profile of pork to a greater degree of saturation. The objective of this study was to characterize the fatty acid profile of pork bellies processed for bacon when 0.6% CLA is fed to finishing market pigs for 60 d prior to slaughter. Also, the processing attributes of the subsequent bacon was assessed. Forty barrows were individually penned, fed, and assigned to a 2 x 2 factorial arrangement within a completely randomized design. Factors included dietary fat source (choice white grease (CWG) or soybean oil (SBO)) with or without the inclusion of CLA with 10 replications per treatment. Diets were balanced for lysine content and each contained 4% added fat. Pigs were fed for 60 d prior to slaughter and resulted in 130±2.6 kg final body weight. Both bellies from each pig were removed from carcasses after 24 h chilling. Bellies were pumped to a 15 % target with a salt and sodium nitrite brine solution. Bacons were chilled, sliced with high speed slicers and packaged shingle style in a commercial processing facility. Data analysis revealed no significant changes for green belly weight, chilled bacon weight, sliced belly weight or bacon yield as a function of green weight or chilled weight when considering CLA or fat source. Weight of bacon ends and pieces decreased ($P=0.04$) when CLA was fed with SBO. Cooking loss of bacon slices was greater ($P=0.04$) for CLA bellies. Differences were not evident for raw or cooked bacon slices regarding slice length or weight for any treatment. Total saturated fats increased ($P=0.001$), total monounsaturated fats decreased ($P=0.001$) and total polyunsaturated fats decreased ($P=0.01$) in CLA bacons. These changes were regardless of dietary fat source. In conclusion, bacon yield and processing characteristics were not significantly changed by feeding CLA to market pigs. However, the fatty acid profile was shifted to more saturation giving the potential for less lipid oxidation of bacon during shelf storage.

**Key Words:** conjugated linoleic acid, fatty acid profile, bacon

**84 The impact of conjugated linoleic acid and distillers dried grains with solubles on pork fat quality.** K. A. Varnold*[1], L. Ochoa[1], S. M. Scramlin[1], J. M. Eggert[2], M. Ellis[1], F. K. McKeith[1], and J. Killefer[1], [1]*University of Illinois, Urbana,* [2]*Newsham Choice Genetics, West Des Moines, IA.*

Feeding diets containing distillers dried grains with solubles (DDGS) decreases fat quality while diets containing conjugated linoleic acid (CLA) have positive effects on fat quality. The objective was to determine if adding CLA to diets containing DDGS would improve fat quality in fresh and processed pork. Pigs (n=90) were allotted to a 2x3 factorial in a randomized complete block design, with 2 levels of DDGS (0 and 30%) and 3 levels of CLA (0.0, 0.5, and 1.0%). Pigs were fed DDGS diets for 8 weeks; CLA was added to diets for the final 4 weeks of the study. Carcass, loin, and belly quality measurements were performed within 48 hours of harvest. Samples from jowl and backfat were analyzed for fatty acid profiles and iodine values were determined. Boneless Boston butts were made into sausage patties and assigned to 4 different freezer storage periods (0, 4, 8, and 12 wk). Thiobarbituric acid reactive substances (TBARS) were determined from patties to measure oxidation. A trained panel scored the amount of fat smearing from pictures of sausage patties. Data were analyzed using PROC Mixed of SAS with repeated measures included for TBARS analysis. Overall, DDGS had a negative impact on quality characteristics while CLA had a positive impact. DDGS decreased firmness of the loin ($P<0.05$), increased ultimate pH of the loin ($P<0.01$), and increased iodine values for both back and jowl fat ($P<0.01$). Inclusion of DDGS caused ratios of monounsaturated: polyunsaturated fatty acids to decrease in both back and jowl fat ($P<0.01$) and ratios of saturated:unsaturated fatty acids to decrease in backfat samples ($P<0.01$). After 4, 8, and 12 wks of storage, adding DDGS increased TBARS values ($P<0.05$). DDGS increased fat smearing ($P<0.05$). DDGS also increased belly pump yield and cook yield ($P<0.05$) and decreased flop distance ($P<0.01$). The effect of CLA was linear for most traits evaluated. CLA decreased 10th rib fat thickness ($P<0.05$) and decreased iodine values in backfat ($P<0.01$). Inclusion of CLA caused ratios of saturated:unsaturated fatty acids to increase in backfat samples ($P<0.01$). At 4, 8, and 12 wks of storage, increasing CLA decreased sausage TBARS values ($P<0.01$). As CLA increased, fat smearing decreased ($P<0.01$). CLA decreased belly pump yield and cook yield ($P<0.05$) and increased green weight and flop distance ($P<0.01$). There were no significant interactions between DDGS and CLA treatments, but effects of each were additive. For example, fat smear scores from 30% DDGS and 1.0% CLA were similar to that of 0% DDGS and 0% CLA. This study confirms that inclusion of DDGS negatively impacts pork fat quality, while inclusion of CLA positively impacts pork fat quality. These data suggest that adding CLA to diets containing DDGS lessen some of the negative impacts of DDGS on fat quality.

**Key Words:** pork, DDGS, CLA

**85 Influence of reduced residual feed intake on composition and quality of fresh pork.** R. M. Smith*[1], J. M. Young[1], W. Cai[1], M. J. Anderson[1], R. C. Johnson[2], E. Huff-Lonergan[1], J.

Dekkers[1], and S. M. Lonergan[1], [1]*Iowa State University, Ames*, [2]*Farmland Foods, Dennison, IA.*

Selection for improved growth efficiency has the potential to alter meat composition and meat quality. The objective of this study was to determine the extent to which selection for reduced residual feed intake (RFI) affects pork composition and quality. In order to achieve this, traits were compared across lines and residual correlations were determined between measured RFI and pork composition and quality. The two lines compared were a line selected for reduced RFI over five generations (select) and a randomly selected control line (control). Selection for reduced RFI resulted in 0.052 kg lower RFI per day. Yorkshire gilts (select = 80, control = 89) were harvested at ~114 kg and the boneless loins were collected at 24 h postmortem. Back fat and loin eye depth were collected off the midline at the last rib region using the Fat-O-Meater. Quality attributes were measured at 2 d postmortem. Drip loss and water holding capacity were measured in duplicate (3 d postmortem). Hunter L, a, and b values were measured in triplicate on two chops using a C10 illuminant, 10° observer, and 1.27cm aperture. Quality scores were assigned by a 3 member panel. Intramuscular lipid and moisture content were determined by AOAC guidelines. Desmin degradation was measured at 2 and 7 d postmortem. Purge, cook loss, sensory traits, and star probe texture were measured at 7-10 d postmortem on cooked (71°C internal temperature) chops. The model included fixed effects of line, slaughter date, MC4R genotype, barn group, line by slaughter date, genotype by line interactions, covariate of off-test weight, and sire, pen, and litter fitted as random effects. Compared to the control line, carcasses from the select line tended to have less (P=0.09) backfat (15.2 ± 0.9 vs. 17.3 ± 0.7 mm), greater (P<0.05) loin depth and greater (P<0.05) calculated percentage of fat free lean (56.5% vs. 54.8%). Select line chops tended to have greater water holding capacity (P=0.07). Loin chops from the select line had less (P<0.01) intramuscular lipid content (1.14% vs. 1.67%), and lower subjective marbling scores (P<0.05) than control chops. Loin chops from the select line carcasses also had a greater (P<0.01) percentage of moisture than the control chops. There were no differences between lines for hot carcass weight, pH, drip loss, Hunter L and a values, subjective color, firmness, and wetness scores, amount of intact desmin at 2 or 7 d, any sensory traits, or star probe values. RFI was correlated (r=0.24, P<0.01) to tenderness and negatively correlated (r= -0.26, P<0.01) to star probe. The residual correlation of intact desmin at 2 d postmortem was not significant, but RFI was correlated (r= -0.18, P=0.02) to the amount of intact desmin at 7 d postmortem. RFI was also correlated (r= -0.15, P<0.05) to chewiness. RFI tended to be correlated (r=0.15, P=0.06) to the percentage of intramuscular lipid. Selection for reduced RFI has the potential to improve carcass composition with few effects on selected measures of meat quality such as pH and water holding capacity. Reduced RFI could negatively affect eating quality due to decreased lipid content and postmortem protein degradation. This work was funded by the National Pork Board.

**Key Words:** pork quality, residual feed intake, carcass composition

**86 Effect of season, transport length, deck location and lairage length on pork quality and blood cortisol concentration.** D. J. Newman*[1], M. H. Ryan[2], C. C. Carr[3], and E. P. Berg[1], [1]*North Dakota State University, Fargo,* [2]*Farmland Foods, Wichita, KS,* [3]*University of Florida, Gainesville.*

The objective was to investigate effects of seasonal environment, transport conditions, and time in lairage on overall pork quality and blood serum cortisol concentrations. Market hogs were harvested during winter, (n=599), spring, (n=660), summer, (n=649), and fall, (n=661) in the Midwestern USA. Within season, pigs were randomly assigned to 1 of 8 treatments in a 2 x 2 x 2 factorial arrangement, with 2 transport durations (short (3 h) or long (6 h)), 2 deck locations (top or bottom) and 2 lairage durations (short (3 h) or long (6 h)). Environmental conditions in the trailer were recorded using data loggers located in top and bottom decks. Blood samples were collected at exsanguination for analysis of plasma cortisol concentrations. Loins were collected at 24 h for pork quality assessment. Longer transport time resulted in higher ($P < 0.05$) cortisol levels than shorter time regardless of season or time in lairage. Within fall and summer, which had the highest cortisol levels, cortisol interacted significantly ($P < 0.05$) with lairage. Pigs lairaged in fall for longer periods had lower cortisol levels than pigs lairaged for a short period of time. Conversely, long lairage in summer had higher cortisol levels than short lairage. Short transport time combined with short lairage duration resulted in lower ($P < 0.05$) cortisol levels than pigs transported longer, regardless of lairage duration. Bottom deck, long transport during summer resulted in higher ($P < 0.05$) cortisol levels. Long lairaged pigs had lower ($P = 0.008$) muscle pH than pigs lairaged a short time in the fall. Long lairage pigs in the summer had higher ($P = 0.001$) pH values than pigs lairaged a short time. Bottom deck tended ($P = 0.06$) to have higher pH and lower drip loss ($P < 0.05$) than top deck in long transport. Comparisons of environmental data with the "weather safety index" reveal that transport conditions have possible negative impacts on welfare and pork quality. More research is needed to understand the link between transport, welfare, and pork quality.

**Key Words:** pork quality, cortisol, transport

**87 Factors affecting the textural properties of pork.** S. F. Holmer*[1], D. D. Duncan[1], C. M. Souza[1], D. L. Clark[1], D. D. Boler[1], L. W. Kutzler[1], A. C. Dilger[1], J. M. Eggert[2], F. K. McKeith[1], and J. Killefer[1], [1]*University of Illinois, Urbana*, [2]*Newsham Choice Genetics, West Des Moines, IA.*

Most of the research concerning rate and extent of tenderization has focused on beef or lamb. However, it is critical to understand these processes in pork especially as retailers move towards minimally processed or non-enhanced product. The objectives of this experiment were to evaluate the textural properties of pork (firmness and tenderness) by examining numerous carcass traits and meat quality measurements which may help explain observed differences in pork loin chops. Pigs from 4 proprietary sire lines (A, B, C, D), but common dam line, were raised under similar management practices and slaughtered on the same day at a commercial facility. Pigs (n=13-16) closest to pen average were selected for each sire and gender, based on live weight. At slaughter carcass data for each pig was collected. From boneless loins, quality measurements for color, marbling, firmness, instrumental color, pH, drip loss, proximate analysis (moisture and fat), collagen content (soluble and insoluble), and sarcomere length were measured. Loins were cut into sections and randomly assigned to aging days of 1, 14, 28, or 42 d postmortem. After the respective aging periods, chops were cut from each section and individually vacuum packaged and frozen at -30 °C. Chops for Warner-Bratzler shear force (WBSF) were cooked to an internal temperature of 70 °C. Cook loss and cooked proximate

analysis were measured on the same chop used for WBSF. To investigate rate and extent of tenderization, loins were evaluated on an individual basis and assigned to categories based on the change in WBSF from one aging day to another. Loins which had a change in WBSF of ±0.3 kg between aging days were characterized as more tender (MT) or less tender (LT). Loins which did not change were characterized as no change (NC). Subjective firmness scores had the highest ($P \leq 0.05$) correlation to pH ($r = 0.41$). Stepwise regression analysis with pH, marbling, and L* value in the model explained approximately 30% of the variation in firmness. Analysis of WBSF indicated no effect of sire, gender, or their interaction ($P > 0.05$), but a significant aging day effect ($P \leq 0.05$) on WBSF. There was no one factor that was consistently correlated to WBSF at all aging days. When there was a significant correlation between a measured trait and WBSF at a specific aging day, the correlation was generally low ($r < 0.30$). Stepwise regression analysis of WBSF at each aging day resulted in regression equations that explained less than 35% of the variation in tenderness. The regression equations were not consistent over aging day and did not include any of the classic traits usually used to predict tenderness (pH, intramuscular fat, or sarcomere length). Changes in WBSF and the measured traits resulted in few significant ($P > 0.05$) and consistent correlations. Loins which were categorized as MT or LT from day 1 to day 42 did not differ ($P > 0.05$) for many of the measured traits. Under the conditions of this experiment, some individual samples continued to tenderize out to 42 d postmortem. The high degree of variation in tenderness was not consistently or completely explained by any group of measured factors. Therefore, future research should focus on characterizing factors that contribute to the textural properties of pork.

**Key Words:** firmness, pork, tenderness

**88 Sodium and potassium carbonate and bicarbonate quality effects on PSE and normal pork gels.** S. Y. Garza*[1], B. L. Booren[2], and R. K. Miller[1], [1]*Texas A&M University, College Station*, [2]*American Meat Institute Foundation, Washington, DC*.

The objective was to examine effects of potassium carbonate (KCO), potassium bicarbonate (KHCO), sodium carbonate (NaCO), sodium bicarbonate (NaHCO), and sodium phosphates (SP) addition on pH, color, water holding capacity (WHC), cook yield, and texture of PSE and normal pork gels. Fresh, whole *Longissimus dorsi* (LD) normal (pH 5.6-5.9) and PSE ($pH \leq 5.4$) muscles were obtained. Loin pH and Minolta CIE (L*, a*, b*) color space values were measured. Within meat type, loins were ground to 0.476cm, segmented into 300g portions, and randomly assigned to treatment. Double-distilled deionized aqueous (ddW) treatment solutions were prepared: negative-control, no added solution (C); positive control (ddW); 0.1, 0.2, and 0.3% (w/v) SP; and 0.1, 0.2, 0.3M of KCO, KHCO, NaCO, or NaHCO. Solutions were added at 12% of ground meat weight, homogenized, vacuum packaged, and stored at 4°C. Three - 0.5g aliquots were weighed onto filter paper and pressed (Carver Laboratory Press, Model C) between two 10.2cm² metal sheets at 500 psi for 60 sec and WHC was determined. Five - 15g aliquots were stuffed into 15mL tubes, centrifuged, cooked to 75°C in a water bath, and stored a minimum of 8 hr at 4°C. Cook yield was calculated and cooked L*, a*, b* color space and pH values were measured at internal cut surface of each gel. Texture profile analysis (TPA) was performed using a TA-XT2i Texture Analyzer with a 50mm dia plunger attachment and 25kg load cell. Five meat gel samples, 1:1 ratio, were compressed to 75% of initial length with 5 sec

delay between compressions. Hardness 1 (N), hardness 2 (N), cohesiveness, gumminess (N), springiness (mm), chewiness (N*mm), work 1 (J), and work 2 (J) were calculated. Three replications were conducted. Data were analyzed using Proc GLM (SAS v9.2, Cary, NC) with a significance level of $P<0.05$. Least squares means with main effects of meat type, treatment, and their interactions were calculated. LD muscles differed in raw pH ($P<0.0001$), L* ($P=0.0037$), and a* ($P=0.0057$) color space values due to PSE meat type. C and ddW gels had lower pH, higher L*, and lower a*and b* values, than treated gels. As treatment levels increased, gels had higher pH, lower L*, and higher a*and b* values. Moisture content across meat type and treatments did not differ ($P=0.8702$). PSE gels with 0.3M KCO had higher WHC ($P=0.0267$) and cook yield ($P<0.0001$) than normal C gels. PSE gels with 0.3% SP had lower WHC ($P=0.0297$) and cook yield ($P<0.0001$) than normal C gels. As levels of KCO and NaCO increased, gels were softer, less cohesive, gummy, chewy, and lower in work 2. SP gels had higher L*, and lower a*, b*, pH, WHC, cook yield, and higher TPA values compared to KCO, KHCO, NaCO, and NaHCO indicating treatments affected texture changes. KHCO and NaHCO gels of both meat types had higher pH, WHC, and cook yield than normal C gels; however, the same attributes were substantially higher in KCO and NaCO gels. For both meat types, TPA values improved for KHCO and NaHCO gels compared to normal C gels, but did not differ from SP gels. KCO and NaCO are feasible alternatives for SP to improve overall quality and functionality of normal and PSE pork.

**Key Words:** PSE, carbonate, bicarbonate

**89 Distribution of mercury in whitefish muscle and methods to reduce the contaminant level.** Y. Gong*[1], B. Egelandsdal[2], and M. P. Richards[1], [1]*University of Wisconsin, Madison*, [2]*Norwegian Food Research Institute, AAS-NLH, Norway*.

Fish are an important part of a healthy diet. However, consumption of foods containing mercury above threshold levels can create health problems particularly in the absence of dietary selenium. This research was done to establish where mercury is concentrated in fish muscle. Another objective was to develop methods to lower mercury levels in fish-based foods. Triacylglycerols (neutral lipids) and cellular membranes were physically isolated from the muscle using centrifugation techniques. Myosin was chemically extracted. Total mercury content in the isolates and the whole muscle was determined by the USEPA method 1631 using a cold vapor atomic fluorescence spectrometer. Acid-sedimentation of membranes and subsequent isoelectric precipitation (acid process) was done to prepare protein isolates from the muscle. These protein isolates are mostly free of neutral lipids and cellular membranes, which has the potential to lower mercury content in the protein isolate. Lake Whitefish (Coregonus clupeaformis) muscle was examined. The total lipids, total phospholipids, and moisture in the whole muscle were 3.19, 0.51, and 77.9 g/100g (wet weight), respectively. Mercury content in dried, whole muscle was 439 ng/g. Neutral lipids and dried membranes contained 244 and 283 ng/g, respectively. Dried myosin contained 69 ng/g. The protein to lipid ratio was 0.19 in the whole muscle compared to 0.07 in the protein isolate prepared by the acid process. Using calculated estimates of neutral lipid, cellular membrane, and myosin content in the muscle, these fractions accounted for around 20% of the total mercury present in the whole muscle. A metal chelator (EGTA) was required to prepare the myosin isolate which may have removed some mercury from the sample. These

studies suggest that the acid process can be used to prepare fish-based foods from whitefish with lower mercury content compared to the starting material.

**Key Words:** mercury, whitefish, muscle

**90 How is the instrumental color of meat measured?** N. W. Tapp*, J. W. S. Yancey, and J. K. Apple, *University of Arkansas, Department of Animal Science, Fayetteville*.

Over 750 peer-reviewed journal articles, from 1998 through 2007, were used to gather instrumental meat color measurement information that was analyzed by the frequency procedure of SAS to illustrate the various methods of measuring meat color. The majority of articles, published in *Meat Science* (79.5%), *Journal of Animal Science* (11.4%), and *Journal of Muscle Foods* (9.4%) originated from European countries (46.2%) and the United States (31.5%). The predominant specie was pork (43.7%), followed by beef/veal (32.6%), lamb/goat (7.9%), and finally poultry (5.4%), and most researchers used Minolta (59.9%) over Hunter Lab (31.6%) colorimeters. Much of the research was done using illuminant D65 (35.6%) followed by illuminant C (8.7%); nevertheless, almost half (47.0%) of the articles did not report the illuminant. When measuring the beef color, 5.2, 2.9, and 10.8% of the researchers reported using illuminants A, C, and D65, respectively, whereas 1.5, 3.5, and 18.9% of the articles reported using illuminants A, C, and D65, respectively, for measuring the color of pork and pork products. Only 0.9 and 1.8% of the articles reporting using illuminants C and D65, respectively, when measuring the color of lamb/goat, and, when measuring the instrumental color of turkey/chicken, illuminants A, C, and D65 reported a mere 0.6, 0.5, and 1.3% respectively, in the reviewed articles. In articles originating in European countries, illuminants A (26.2%), C (2.5%), and D65 (16.7%) were most commonly noted, but 26.2% of the European articles failed to report the illuminant used to collect color data. On the other hand, 8.1% of the articles were attributed to the U. S. and did not indicate illuminant, and the majority of U. S. articles reported using illuminants A (6.6%), C (4.1%), and D65 (12%). A majority of the articles did not report an aperture size (71.7%), but 8 (7.9%), 25 (7.8%), and 10 mm (3.9%) were the prevalent aperture sizes used to measure instrumental meat color. Again, 62.5% of the articles did not report the observation angle, but 27.4% reported an angle of observance of 10°. Furthermore, the vast majority of the articles (71.4%) failed to reported the "bloom" time between cutting or package removal and color data collection; yet, 7.8% of the articles utilized a 30-min "bloom" time, followed by a 60-min "bloom" time (6.6%). Chi-square analysis indicated that 63.0% of all articles did not report the number of readings per sample used when collecting their data, but 13.6% of the articles reported taking 3 readings per sample. When measuring darkness-to-lightness, L* values were reported more often than L values (86.3 vs. 10.5%). Moreover, a* values were preferred over a values (85.3 vs. 10.8%) when measuring the green-red color axis, and a greater proportion of articles reported using b* instead of b values (83.6 vs. 9.9%) when measuring the blue-yellow color axis. These results indicated that: 1) a large percentage of the articles failed to include information (i.e., illuminant, aperture size, observation angle, "bloom" before data collection, and number of readings per sample) necessary to replicate and accurately interpret instrumental color results, and 2) because of the wide range of reported parameters/protocols, the procedures for instrumental color data collection, and how they are to be cited, may need to be standardized.

**Key Words:** color measurement, colorimeter, illuminant

**91 Heritability estimates of beef lean color stability.** D. A. King*, S. D. Shackelford, L. A. Kuehn, T. L. Wheeler, and R. M. Thallman, *USDA, ARS, US Meat Animal Research Center, Clay Center, NE*.

Anecdotal evidence suggests that some carcasses produce cuts with insufficient lean color stability to meet specifications for case-ready programs. The source of animal-to-animal variation in lean color stability has not been adequately characterized to determine a suitable solution to this issue. Our objective was to determine the genetic contribution to lean color stability of beef produced by a crossbred cattle population representing the most commonly used breeds in the industry. Sires were sampled from seven breeds (Angus, Charolais, Gelbvieh, Hereford, Limousin, Red Angus, and Simmental) to produce F1 bulls and heifers. These animals were multi-sire mated to create F1 x F1 (F1-2) steer progeny (n = 464 over two years), which were fed a corn-based diet, serially slaughtered, and subsequently evaluated for lean color and lean color stability. Thirty-two sires produced progeny (average of 14.4 progeny per sire) used in this experiment. Parentage was verified using SNP markers. At 18 d postmortem, one longissimus thoracis steak obtained from each animal was packaged in PVC-overwrap and placed in simulated retail display for 6 d. Instrumental color measurements (L*, a*, b*, and spectral data) were collected on d 0 and d 6 of display. These data were also used to calculate the change in chroma, overall color change (delta E), and K/S 572:K/S 525 (surface metmyoglobin) during display. Initial L* (lightness), a* (redness), and b* (yellowness) values were 48.6 ± 0.14, 33.7 ± 0.07, 26.5 ± 0.09, respectively. Final values of L*, a*, and b* were 47.1 ± 0.15, 26.6 ± 0.12, 21.4 ± 0.09, respectively. At the initiation of display, 24% of the variation in L* values could be explained genetically. By day 6, 40% of L* variation could be explained by genetics. Neither a* nor b* values were heritable when measured on day 0; but genetic contributions to d 6 measurements could account for 14 and 13% of variation in a* and b*, respectively. Change in L* values was not heritable. The changes in a* and b* between d 0 and d 6 were more heritable than the values measured either before or after display. Changes in color intensity (chroma), redness (a*), overall color change (delta E), and the accumulation of surface metmyoglobin (K/S 572:K/S 525) were moderately heritable. Greater heritability estimates associated with the changes in these variables suggest that the genetic contribution to lean color is more related to the ability to maintain lean color rather than determining initial color. These heritability estimates suggest that genetic selection could potentially be used to increase the color stability of meat products.

**Heritability estimates of beef longissimus thoracis lean color attributes measured before or after retail display**

| Trait | Day 0 | Day 6 | Change |
|---|---|---|---|
| L* | 0.24 | 0.40 | 0.00 |
| a* | 0.06 | 0.14 | 0.31 |
| b* | 0.00 | 0.13 | 0.23 |

| | | | |
|---|---|---|---|
| Delta E | - | - | 0.29 |
| Chroma | - | - | 0.35 |
| K/S 572:K/S 525 | - | - | 0.29 |

**Key Words:** beef, color stability, heritability

**92 Partial amino acid sequence of turkey myoglobin.** P. Joseph*[1], S. P. Suman[1], S. Li[1], L. Steinke[2], M. Fontaine[2], and J. R. Claus[3], [1]*University of Kentucky, Lexington*, [2]*University of Nebraska, Medical Center, Omaha*, [3]*University of Wisconsin, Madison*.

The role of turkey myoglobin (Mb) and its interactions with various ligands on pink color defect have been documented. However, limited efforts were undertaken to characterize the biochemistry of turkey Mb. In our recent investigation, the molecular mass and thermostability of purified turkey Mb were determined in comparison with beef Mb, wherein turkey Mb exhibited greater molecular mass and greater thermostability than beef Mb. In order to further elucidate the unique biochemistry of turkey Mb, its amino acid sequence should be determined. In the post-genomic era, the primary structure of myoglobins from several meat-producing livestock and bird species has been determined, whereas that of turkey Mb is yet to be characterized. Therefore, the objective of the present study was to determine the amino acid sequence of turkey Mb. Turkey Mb was isolated from cardiac muscles via ammonium sulfate precipitation and gel-filtration chromatography. Purified turkey Mb in SDS-PAGE gel was digested with trypsin. The tryptic-peptides were separated in reverse-phase HPLC, analyzed in mass spectrometer, and subjected to Edman degradation, which revealed the identity of 45 residues from the amino terminus. Turkey Mb shared less than 80% similarity with beef Mb in the forty-five amino acid segment; the residues at eleven positions were different in turkey and beef myoglobins. On the other hand, turkey and chicken myoglobins shared 100% similarity in the forty-five amino acid segment. Ratite (ostrich and rhea) myoglobins exhibited more than 80% similarity with turkey Mb in the corresponding segment. The present study is the first to report the partial amino acid sequence of turkey Mb. Our results indicated that the primary structure of turkey Mb is different from those of beef and ratite myoglobins. In addition, the differences in the primary structure of turkey and beef myoglobins may be attributed, partially, to the reported differences in thermostability. Furthermore, these findings suggested the necessity to engineer species-specific processing strategies to minimize the occurrence of color defects in cooked as well as fresh meats.

**Key Words:** turkey, myoglobin, primary structure

**93 Primary structure and oxidative stability of bison myoglobin.** P. Joseph*[1], S. P. Suman[1], S. Li[1], C. M. Beach[1], L. Steinke[2], and M. Fontaine[2], [1]*University of Kentucky, Lexington*, [2]*University of Nebraska, Medical Center, Omaha*.

Bison is an emerging alternate red meat species and has unique health-promoting attributes such

as low fat and low cholesterol contents. Consequently, consumer demand for bison has been increasing in the United States and Canada. On their investigations to differentiate bison from beef, based on quality attributes, several researchers reported rapid discoloration in bison compared to beef. Nonetheless, the fundamental basis for the difference in color stability between bison and beef is yet to be investigated thoroughly. Therefore, our objective was to characterize the oxidative stability and primary structure of bison myoglobin (Mb), in comparison with beef Mb. Bison and beef myoglobins were purified from cardiac muscles. Autoxidation and lipid oxidation-induced oxidation were analyzed at typical meat storage and physiological conditions in bison and beef oxymyoglobins. Matrix Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry was utilized to determine the molecular mass of bison Mb, whereas Edman degradation was employed to determine the amino acid sequence. Bison and beef oxymyoglobins exhibited similar trends in autoxidation and lipid oxidation-induced oxidation at typical meat storage and physiological conditions. Analyses of mass spectra indicated that bison and beef myoglobins have the same molecular mass (16,948 Daltons). Furthermore, sequence analyses yielded the complete primary structure of bison Mb, which shared 100% similarity with beef and yak myoglobins. However, bison Mb's sequence was different from those of other ruminants, such as water-buffalo, sheep, goat, and red-deer. Bison Mb shared 98% similarity with water-buffalo Mb, 98.7% similarity with sheep Mb, 97.4% similarity with goat Mb, and 98% similarity with red-deer Mb. This study is the first to report the primary structure of bison Mb. The similar biochemical attributes and primary structure of bison and beef myoglobins suggested that the faster discoloration in bison than in beef could be due to endogenous factors other than Mb chemistry. Further research is necessary to elucidate the possible role of sarcoplasmic proteome on differences in color attributes of bison and beef.

**Key Words:** ison, myoglobin, primary structure

**94 Structural factors affecting pigment oxidation, hemin loss, and lipid oxidation due to bovine hemoglobin and bovine myoglobin.** H Cai* and M. P. Richards, *University of Wisconsin, Madison*.

Lipid oxidation causes product discoloration, off-flavors and off-odors. Hemoglobin (Hb) and myoglobin (Mb) have been shown to promote lipid oxidation in various models and residual Hb in muscle after bleeding can be substantial. Pigment oxidation, namely autooxidation, occurs when the iron atom in heme of Hb or Mb is converted from the ferrous state (Fe2+) to met state (Fe3+). Met formation weakens the porphyrin-globin linkage. Hemin (Fe3+) loss is the dissociation of hemin from the globin. Subsequently, hemin decomposes pre-formed lipid hydroperoxides into free radicals which readily stimulate the oxidation of lipids. Our objective was to examine the relative ability of bovine Hb and Mb to autooxidize, release hemin, and promote lipid oxidation. Another objective was to assess structural factors that could explain oxidative differences between Hb and Mb. Bovine Hb was separated from the soluble contents of lysed erythrocytes using gel filtration chromatography. Bovine Mb was expressed from BL21(DE3) E. coli containing the recombinant bovine Mb gene, and purified Mb was obtained via salting out, DEAE and mono-Q IEX chromatography. Autooxidation rates were determined through the absorbance changes at 630, 576, and 560 nm by UV-Visible spectrometry. Hemin loss rates were determined using the apo form of H64Y sperm whale myoglobin of which the

holo form has unique spectral property (strong absorbance at 600 nm) compared to native ferric myoglobin. Met Hb and met Mb were separately added to washed muscle fibers at 2°C (pH 5.7) and lipid oxidation products (lipid peroxides and TBARS) were measured periodically during storage. Site directed mutagenesis was used to prepare bovine Mb mutants. Crystal structures of bovine Hb at various pH values were compared to structures of sperm whale Mb (80% identity with bovine Mb). At pH 5.7, Mb autooxidized 11-fold faster than Hb. In contrast, the rate of hemin loss from metMb was 60-fold slower compared to metHb at pH 5.7. Met Hb more effectively promoted lipid oxidation in washed muscle fibers compared to met Mb at pH 5.7. This indicated that hemin release promoted lipid oxidation more so than autooxidation rate. It also indicates Mb has a greater tendency to turn brown compared to Hb. Multiple amino acid differences between bovine Hb and bovine Mb can explain the rapid autooxidation of Mb (with slow hemin loss) compared to the rapid hemin loss from Hb (with slow Hb autoxidation). A lattice of hydrogen bonds and electrostatic interactions that coordinate amino acid side chains to the heme propionate groups are present more so in Mb compared to Hb which explains the high hemin affinity of metMb. Serine is present at site E14 in hemoglobin β chains while alanine is present in myoglobin and hemoglobin α chains. Substituting alanine with serine in bovine Mb decreased hemin affinity. This can be explained by the polar serine destabilizing the hydrophobic edge of the heme ring. The ability of larger residues in Hb to block solvent from the heme crevice of ferrous heme protein can partly explain the decreased autooxidation of Hb compared to Mb. These studies present underlying mechanisms of pigment oxidation and lipid oxidation in muscle which can aid in the development of novel antioxidant strategies.

**Key Words:** lipid oxidation, hemoglobin, myoglobin

**95 Addition of reduced bovine serum albumin to a heme-phospholipid model affects lipid and protein degradation.** B. Egelandsdal*[1,3], L. P. Ren[2,3], Y. S. Gong[3], M. Greaser[3], and M. P. Richards[3], [1]*University of Life Science, Ås, Norway*, [2]*China Agricultural University, Beijing, China*, [3]*University of Wisconsin, Wisconsin*.

Increased use of polyunsaturated lipids in foods may require a better understanding of the oxidation progress to prevent quality problems. Marine phospholipids and hemeproteins, in a washed cod model, have been demonstrated as potent components for initiating lipid degradation and the formation of secondary lipid oxidation products. In this study we have evaluated the potential antioxidant capacity of muscle thiols through quantification of accessible thiols in the fish muscle as well as by quantification of the thiols of a protein additive, bovine serum albumin (BSA). BSA has 33 cysteines and normally 3 are regarded as reducible. BSA carried into the model system 3-4 thiols for each BSA molecule added .The extensively washed fish muscle had approximately 2/3 of its accessible thiols as free thiols. The remaining 1/3 could be accessed after reduction with dithiotreitol.
Thiols were measured using the reaction with 5,5' – dithiobis (2 nitrobenzoic acid); peroxides were quantified through their reaction with ammonium thiocyanate; thiobarbituric acid was used for measuring secondary oxidation products (TBARS) and the cathepsin L+B activities were assessed through the use of their substrate Z-Phe-Arg 4-methoxy-methylcoumarin hydrochloride. When this experiment was carried out (after storing the fish muscle for 3 months at -80°C) the amount of thiols coming from fish protein was around 8 mmol/kg total sample. The amount of

thiols added through BSA addition was 0.37 mmol/ kg total sample. The addition of bovine serum albumin (BSA) to the system reduced the formation of lipid peroxides and TBARS. The delay in the increase in lipid peroxides was approximately 9 hrs during the observation period of 47 hrs. Fish proteins were continuously degraded, or at least released, as lower molecular weight proteins/peptides. The thiol proteases cathepsin B + L were stimulated by the addition of reduced BSA, and throughout the observation period of 47 hrs, the system with reduced BSA had a higher activity than systems with metmyoglobin added. It is frequently assumed that the reducing power of thiol groups is limited below pH 7.0, since the pKa of thiol groups are quite high (typically above pH 8.0). But this experiment was carried out at pH 5.6 and still a significant reduction in lipid degradation components was observed. In addition, the amount of added thiols was relatively small. Possibly the radical scavenging ability of BSA also affected the results. The results from the washed cod model should be relevant to pork, beef and poultry products as well, in terms of flavor formation mechanisms, although the kinetics of lipid degradation would be slower in those products due to the presence of less reactive heme-proteins and more saturated phospholipids in such products.

**Key Words:** lipid degradation, thiol changes, proteolysis

**96 Non-linear mixed effects model for statistical analyse of differences in cooking loss in aging.** A. Dufek*[1], J. Riha[2], J. Subrt[3], J. Simeonovova[3], and M. Homola[1], [1]*Agriresearch Rapotin, Ltd, Vikyrovice, Czech Republic*, [2]*Research Institute for Cattle Breeding, Ltd, Vikyrovice, Czech Republic*, [3]*Mendel University of Agriculture and Forestry, Brno, Czech Republic*.

We used the package nlme (non-linear mixed effects) in program R for description and statistical analysis of non-linear relationships between cooking loss and aging time. We applied the practical tool, which offer the possibility of many diagnostic plots, to evaluate 2x2 experimental design (bulls, heifers) x (extensively, intensively fattened) with 5-6 animals in each subgroup was performed during 2 years (n=45). Extensively fattened animals were bred in the grass-based fattening system in the low favored area. The animals were grazing in the vegetative season and were fed grass silage in winter. Intensively fattened animals were reared in the same area and were fed concentrate diet in feedlots. A part of MLLT was removed from every carcass at 24 h post-mortem. The part was divided to 4 samples and they were individually vacuum packed. One of the samples was analyzed 48 hours post-mortem. The other three samples were stored at 2-4 °C for aging period on the following 16, 30 and 44 days (2-weeks intervals). Cooking loss was determined by weighing the samples before and directly after cooking in a water bath in which the internal temperature of the samples reached 70°C for one hour. Percentage of total cooking loss (evaporative and drip loss) was calculated as: cooking loss=((raw weight-cooked weight)/raw weight) x 100. We described the relationship between aging time and cooking loss by the asymptotic regression model "cooking loss=Asym+(R0-Asym) exp[-exp(lrc)Time" with three physically meaningful parameters: R0 – the response in the (slaughter) time 0, lrc – logarithm of the rate constant and Asym – a response that approaches a horizontal asymptote. Values of the parameters for the model including all animals were R0=23.5 %, lrc=-2.18, Asym=32.96%. The models fitted within each group separately were R0=25.03 %, lrc=-2.32, Asym=37.63 % for extensively and 24.96, -2.27, 32.97 for intensively fattened bulls, 23.52, -

2.37, 32.32 for extensively and 18.92, -1.39, 29.52 for intensively fattened heifers, R0, lrc, Asym respectively. To find out real differences between the experimental groups we used the mixed model, where the animal nested in year was as the random effect, because of repeated measures on one subject, and nested in year, because the experiment was conducted in two years. There were also added covariates into the model (age at slaughter time and mass of carcass), because the values varied: the average age at slaughter was 659 days (s.d.=55) and average carcass mass 338 kg (s.d.=67). We used backward selection – we began with a full model and firstly tested significancy of the random effects. After that we looked at the significancy of the covariates and experimental effects. The R0 was affected by the sex ($F=12.4$, $p=0.0006$) not by the diet ($F=0.003$, $p=0.96$). The heifers had lower the R0. The lrc did not differ between groups $F=0.420$, $p=0.5182$ for the diet, $F=1.483$, $p=0.2257$ for the sex. Only the carcass mass had the effect on the lrc $F=4.107$, $p=0.045$ – higher carcasses had higher lrc value. The asymptote was affected by the sex $F= 11.732$, $p=0.0008$ – heifers had lower asymptote than bulls and by the carcass mass $F= 6.223$, $p=0.0140$.

**Key Words:** non-linear model, mixed effects, aging

**97 Inhibition of salt induced oxidation in goat meat by pomegranate (*Punica granatum*) and kinnow (*Citrus reticulata*) rind powders.** S. Devatkal*, K. Narasaiah, A. Borah, and R. T. Patil, *Central Institute of Postharvest Engineering and Technology (I.C.A.R), Ludhiana, India*.

Lipid oxidation is the major cause of deterioration and reduced shelf life in meat products. It leads to discoloration, drip loss, off-odor, off flavor and production of potentially toxic compounds (hydroperoxides, malonaldehyde, free radicals) in meat products. Although synthetic antioxidants like BHT, BHA prevent lipid oxidation, these chemicals are considered to be promoters of carcinogens as well as unacceptable by consumers. Natural antioxidants as an alternative has received much attention in recent years. Pomegranate rind powder and kinnow rind powder are by- products from processing of pomegranate (*Punica granatum*) and kinnow (*Citrus reticulata*) fruits respectively. Preliminary studies have shown that the powders from these fruit by-products are rich sources of phenolic compounds having free radical scavenging activity. Therefore these fruit by-products offer a practical and economic source of natural antioxidants. Keeping this in view, experiments were designed to evaluate the antioxidant effect of fruit by-products viz., pomegranate seed powder (PSP), pomegranate rind powder (PRP), and kinnow rind powder (KRP), in goat meat.
Oxidation in goat meat was induced by adding 5% salt. Five samples of minced goat meat were prepared: I) control -meat, II) meat + 5% salt, III) meat + 5%salt + 2% PSP, IV) meat + 5% salt + 2% PRP and v) meat + 5% salt + 2% KRP. Lipid oxidation was evaluated by measuring thiobarbituric acid (TBA mg/kg meat) during storage at temperature of 4 ±1 °C for 7 days. TBA in control samples increased significantly ($p<0.05$) from 0 .075 to 2.14 mg/kg. In treatment II, TBA markedly increased from 1.32 to 3.96 mg/kg indicating pro-oxidant effect of salt. In sample III, TBA slightly increased from 0.39 to 0.68mg/kg, and was significantly ($p<0.05$) lower than treatments I, II, IV and V during all days of storage. In sample IV, TBA increased from 0.52 to 1.34 mg/kg but was significantly ($p<0.05$) lower than sample I and II. KRP also decreased TBA as compared to treatments I and II. After 7 days of storage, these samples were heated in a water bath (80 °C for 25 minutes) and evaluated for TBA. The average TBA values in PSP samples

(0.265 mg/kg) were significantly lower than control (1.65 mg. /kg), KRP (1.15 mg/kg) and PRP samples (1.237 mg/kg). These results showed that PSP, PRP and KRP used in this study significantly inhibited salt induced oxidation in goat meat and the overall antioxidant effect was in the order of PSP> PRP > KRP.
Further, goat meat patties were prepared incorporating PSP, PRP and KRP. Hunter L* was significantly ($p<0.05$) lower in PRP followed PSP and KRP samples. However no significant difference was observed for Hunter a* and b*. Sensory evaluation on a 6 point descriptive scale indicated a slight off taste in KRP samples and no other significant differences among other samples. Average TBA values ( mg/kg meat ) after 5 days and 10 days of storage at 4±1 ° C were 1.19 and 1.93 in control, 0.68 and 0.972 in KRP, 0.598 and 0.785 in PRP and 0.374 and 0.383 in PSP patties respectively. These results indicated that above fruits by-product powders have potential to be used in meat products as a source of natural antioxidants without affecting the sensory qualities.

**Key Words:** lipid oxidation, natural antioxidants, pomegranate and kinnow rind powders

**98 Shelf life properties of ground beef from carcasses and trimmings treated with lactic acid bacteria.** J. N. Martin*[1], J. C. Brooks[1], A. R. Pond[1], A. Echeverry[1], R. A. Bowling[2], and M. M. Brashears[1], [1]*Texas Tech University, Lubbock,* [2]*Agrifood Solutions International, College Station, TX*.

Lactic acid producing bacteria (LAB) have been approved for use on meat products to control pathogens. However, research was needed to determine their efficacy as carcass applications. The objective of this study was to evaluate the shelf life characteristics of ground beef obtained from beef carcasses treated with LAB ($1 \times 10^{6}$) at harvest, carcass chill and fabrication. In a commercial beef processing facility, beef carcasses (n = 3 per treatment) were randomly assigned to one of four treatments: negative control (CTRL; no application of LAB); hot carcass (HOT; applied after hot water pasteurization); cold carcass (COLD; applied after carcass chilling); and trimming (TRIM; applied to beef trimmings as generated during fabrication). All carcasses were fabricated into beef trimmings after a 24-h chill and transported to a commercial meat grinding operation where the trimmings were processed into coarse ground beef and packaged. Packages of coarse ground beef were transported under refrigeration to Texas Tech University for display and analysis. Each week, over a five-week storage period, the coarse ground beef was further processed into finely ground beef, packaged in a foam tray with film over-wrap and placed into retail display cases maintained at $0^{o}$ C. Samples were evaluated at regular intervals for 72 h to characterize changes in pH, thiobarbituric acid (TBA), lean color and discoloration. Trained panelist used verbally anchored hedonic scales to assess lean color (1 = very bright red to 5 = very dark red or brown) and discoloration (1 = no discoloration to 5 = 61-100% discoloration). pH measurements for all treatments decreased over the five week storage period. CTRL samples produced lower pH values than TRIM throughout the trial, with intermediate HOT and COLD pH measures. TBA values varied over the five week period and during retail display. TBA values tended to increase for all treatments as storage period increased. During retail display, HOT samples had lower TBA values than TRIM, with COLD and CTRL samples similar to both treatments. Lean color scores for all treatments decreased as retail display time increased, but at different rates. At weeks 2 and 3, HOT and COLD samples produced more desirable lean color

scores than TRIM and CTRL treatments. After 5 weeks of storage, HOT, COLD and CTRL had significantly lower lean color scores than TRIM samples. Lean discoloration scores for all treatments increased as storage time increased, indicating meat samples tended to discolor earlier in the display period as storage time increased. Discoloration scores for all treatments were similar after 1 and 2 weeks of storage. After 3 weeks of storage, discoloration scores were higher for HOT compared to CRTL and COLD treatments. After 4 weeks of storage, discoloration scores for HOT were similar to CTRL and higher than TRIM and COLD. After 5 weeks of storage, TRIM samples had significantly higher discoloration scores than HOT, CRTL and COLD samples. These data indicate the application of LAB to beef carcasses at harvest (HOT) and after chilling (COLD) would not have a detrimental impact on shelf life and could extend the shelf life of ground beef produced as described.

**Key Words:** beef, lactic acid bacteria, shelf life

**99 Validation and shelf life properties of beef products treated with lactic acid bacteria.** A. R. Pond*[1], A. Echeverry[1], J. C. Brooks[1], R. A. Bowling[2], and M. M. Brashears[1], [1]*Texas Tech University, Lubbock,* [2]*Agrifood Solutions International, College Station, TX*.

In December 2006 FDA announced their approval for post-harvest application of cultured lactic acid bacteria to meat products. This specific culture (Bovamine®) includes four strains of synergistic lactic acid bacteria (LAB) NP51, NP35, NP07, and NP03. These strains were selected for their ability to reduce pathogens but not grow in refrigeration temperatures. The purpose of this study was to evaluate the shelf life of ground beef obtained from beef carcasses treated with lactic acid bacteria.
In a commercial beef processing facility selected beef carcasses were randomly assigned to one of four different treatments. These treatments included negative control (CTRL; no application of LAB), hot carcass (HOT; applied after hot water pasteurization), cold carcass (COLD; applied before fabrication), trim (TRIM; applied in combo after fabrication). Carcasses were sprayed with $1 \times 10^6$ dose of the product. After application, carcasses were fabricated into trim and transported under refrigerated, dark conditions to Texas Tech University. Each week over a 4 week period, chubs were further processed into ground beef and tested daily over a 72-hour period. For the microbial portion of the study, samples were tested for LAB, aerobic plate counts (APC), generic *E. coli* , and the presence of *E. coli* O157:H7 and *Salmonella* . For the quality part of the study, duplicates were tested for color desirability, discoloration, thiobarbituric acid (TBA) values, and pH.
Meat discoloration was not remarkably different in Weeks 1 and 2 of retail display; however, after week 3, discoloration started to occur with HOT and CONTROL samples 15 to 20 hours before COLD and TRIM samples. Each week over the 72 hour period, the TBA values for treated or control samples were not affected over time. Initial ground beef APC log counts (Week 1) were 3.19, 2.89, 3.37, and 3.72 for CTRL, HOT, COLD, and TRIM, respectively. On week 2 and 3 the initial APC counts ranged between 5.60 to 6.43 and 6.12 to 6.98, respectively. By week 4 of the study, APC counts had increased between 2.3 and 3.4 logs. Of the treated samples, the HOT carcasses presented the lowest APC counts during the 4 week period. The numbers of lactic acid bacteria increased during a 4 week period between 2.4 to 4.15 logs in the ground beef, with only up to 0.5 logs differences observed between HOT and CTRL samples

indicating that LAB do not contribute to spoilage. Application of lactic acid bacteria on COLD and TRIM presented consistently higher numbers than HOT. No *E. coli* O157:H7 or *Salmonella* were detected in any of the samples.
Microbial and sensory testing results obtained from this study indicate that the application of lactic acid bacteria to HOT carcasses presented an extended shelf life for chubs as well as ground beef.

**Key Words:** lactic acid bacteria, shelf life, ground beef

**100 Feeding extruded full-fat cottonseed or white tallow as a source of fat in finishing beef diets: II. Efficiency, objective shelf-life color and fatty acid profiles.** A. M. Stelzleni*, M. A. Froetschel, and T. D. Pringle, *University of Georgia, Meat Science and Technology Center, Athens*.

Twenty-one Angus heifers were fed (UGA Wilkins Beef Research Center) extruded full-fat cottonseed (FuZzy Pellets™ ) or tallow to examine the effects of finishing diets with various fat sources on animal performance, meat color stability, and fatty acid profiles. The main objective of this project was to enhance the concentration of conjugated linoleic acid (CLA) by increasing the substrates for ruminal and endogenous synthesis through the feeding of extruded cottonseed pellets. Heifers were blocked by weight and randomly assigned to one of three total mixed ration finishing diets with 13.0% protein and 7.5% fat, as fed, supplied by: 1) 3.7 % tallow (TAL), 2) 1.9% tallow and 12.5% extruded full-fat cottonseed pellets (TC), or 3) 25.0% extruded full-fat cottonseed pellets (CTN). The heifers were individually fed, ad libitum, for 82 d. At the end of the feeding period, heifers were transported to the University of Georgia Meat Science and Technology Center for slaughter under federal inspection. Twenty-four hours postmortem the longissimus lumborum was removed and steaks were cut (2.54 cm) for objective color analysis (CIE L* a* b*) on d 1, 3, 6, and 10. One steak was also removed from each loin for fatty acid analysis. Ground beef (80% lean, 20% fat) was produced from the pectoralis profundi on d1 for color analysis on d 1, 2, 4, and 7. A ground beef sample was also retained for fatty acid analysis. As well, a subcutaneous fat sample was collected from the longissimus lumborum for fatty acid analysis.
Heifers did not differ ($P>0.05$) in Gain:Feed or Average Daily Gains across treatments or across days (d 1-22, 23-70, and 71-82). Therefore, cumulative Gain:Feed and Average Daily Gains were not different ($P>0.05$). Heifer weight did not differ ($P>0.05$) among treatments for any weight period, but as expected increased ($P<0.05$) as time on feed increased. Steak L* values were similar ($P>0.05$) between TAL and TC, but CTN was darker ($P<0.05$) than either. There was no difference ($P>0.05$) among treatments for steak a* or b* values. Ground beef L* a* and b* values were similar ($P>0.05$) for all treatments. For steaks, L* values did not change ($P>0.05$) as days on display increased, however, a* and b* values declined ($P<0.05$) as time on display increased. Ground beef L* values indicated that it got lighter ($P<0.05$) as time on display increased, however; like the steak samples, a* and b* values decreased ($P<0.05$) as time on display increased. Feeding extruded full-fat cottonseed pellets as the main fat source did not appreciably increase CLA content in the longissimus lumborum, ground beef, or subcutaneous fat samples. Feeding CTN increased ($P<0.05$) total monounsaturated (MUFA), polyunsaturated fatty acids (PUFA), and ω-6:ω-3 in steaks compared to TAL fed heifers. Subcutaneous fat

samples from CTN had increased (P<0.05) saturated fatty acids (SFA), PUFA, and ω-6:ω-3 compared to TAL, but lower (P<0.05) MUFA. Ground beef samples followed the same trend as the fat samples. Feeding extruded full-fat cottonseed pellets as the main fat source does not increase CLA content in beef.

**Key Words:** supplement, fatty acid, beef

**101 Evaluation of the storage life of vacuum packaged Australian beef.** A. Rodas-Gonzalez*, C. Narváez-Bravo, H. B. Rogers, J. L. Tedford, G. O. Clark, J. C. Brooks, B. J. Johnson, J. D. Starkey, M. M. Brashears, and M. F. Miller, *Texas Tech University, Department of Animal and Food Science, Lubbock.*

To establish the shelf-life of vacuum packaged Australian beef, 15 strip-loins and 15 cube-rolls for each processor (companies A, B, C) were evaluated at two week intervals (wk 10, 12, 14, 16, 18, 20) after being received. All strip-loins and cube rolls were repackaged under vacuum after each sampling occasion and stored at 3°C. Steaks on the trays were placed in multi-deck and coffin-style retail cabinets at 3°C, under fluorescent light for three days. Shelf-life evaluation was based on off-odor (only at week 10), microbial analysis (Aerobic plate count, Lactobacillus and psychrotrophic), lipid oxidation (TBARS) and colour assessment (trained panelist and Hunter colorimeter). Panelists detected slightly off-odor in both primal cuts for processor B and C ($P < 0.05$). Post-bloom color evaluation, primal cuts from Processor A were scored bright red at 10 weeks and turned to dull or slightly dark red at 16 weeks, while cuts from processor B and C were scored higher than dull and slightly dark red at 10 weeks and kept these colors during the entire experimental period ($P < 0.05$). In retail pack color evaluation, samples from processor B and C since the first day of display, had remarkable undesirable colors (higher than slightly dark red; $P < 0.05$). Changes in CIE L*, a*, b*, Chroma and Hue values throughout the display of steaks supported the color observations made by the trained panelists. Primal cuts from Processor A showed lower microbial counts with respect to other processors. In all processors, TBARS values decreased over time, being not useful for establishing shelf-life. Processor A cuts showed better attributes (none off-odor, better red color and lower microbial counts) from the beginning that explains its slow shelf-life deterioration.

**Key Words:** shelf-life, vacuum packaging, spoilage bacteria

**102 Effects of two antimicrobials on tenderness and shelf-life stability of enhanced top-round roasts from mature cows.** J. R. Segers*, A. Ponrajan, M. A. Harrison, T. D. Pringle, B. K. Lowe, R. O. McKeith, R. M. Pitzer, and A. M. Stelzleni, *University of Georgia, Meat Science and Technology Center, Athens.*

The purpose of this study was to examine the effects of MOstatin™, and IONAL® (World Technology Ingredients Inc., Jefferson GA) on the physiochemical characteristics of top rounds IMPS 169A (FPL Foods LLC, Augusta GA) from mature cows. This research was conducted in cooperation with FoodPAC (Food Processing Advisory Council) of Georgia. Top rounds (n=60) were procured at d 3 after slaughter, and injected on d 4 to achieve a 10% pickup with 0.5%

NaCL and 0.4% Sodium Tripolyphosphate in the final product for control (CNT) plus 2% MOstatin™ (MO) or 1% IONAL® (IN). After injection, samples were vacuum sealed and allowed to rest for 10 d (0°C) to mimic storage and transportation. Before and after each injection pH measurements were taken as well as d 10. After d 10, 2.54 cm steaks were fabricated and packaged (PVC over-wrap) for shelf-life (SL) and stored under luminescence at 4±1°C for 7 d with subjective and objective (Minolta L*a*b*) color taken daily. Subjective color was evaluated on an 8 point scale in 3 categories: overall acceptance (OA;8=very acceptable, 1=unacceptable), color (COLOR;8=light reddish pink, 1=dark purple/brown), and discoloration (DIS;8=no discoloration, 1=complete discoloration). At d 1, 7, 14 samples were removed for lipid oxidation analysis (TBARS). Five cm roasts were fabricated for Warner-Bratzler shear force (WBS) and aged (0°C) until d 10, 17, 24, and 31 post injection. Data was collected for percent thaw loss (PTL), percent cook loss (PCL), cook time (CT), and endpoint temperature (TEMP).
Subjective measurements indicate that OA and COLOR decreased ($P<0.05$) as SL increased; however, treatment was not significant ($P>0.05$). For DIS there was a treatment x age interaction ($P<0.05$). L* values decreased ($P<0.05$) with age between d 0 and d 7; however, treatment had no effect ($P>0.05$). IONAL™ decreased ($P<0.05$) a* compared to CNT, but MO increased ($P>0.05$) a* compared to IN. As well, a* decreased ($P<0.05$) between d 0 and 7 of SL. Treatment and SL influenced b* ($P<0.05$) with MO having a greater value ($P<0.05$) than IN, and decreasing ($P<0.05$) as SL increased. A treatment x time interaction ($P<0.05$) occurred for pH taken before and after injection. Control roasts had a greater ($P<0.05$) PTL than IN or MO while IN exhibited reduced ($P<0.05$) PTL compared to MO. Increased ($P<0.05$) PTL occurred between d 1 – 14 and d 7 – 21. Percent CL was higher ($P<0.05$) for CNT compared to IN or MO, and IN had lower ($P<0.05$) PCL when compared to MO. Cook time significantly decreased ($P<0.05$) as aging increased. There was no difference ($P>0.05$) between treatment and aging for TEMP. Percent purge was greater ($P<0.05$) for MO than CNT or IN. Treatment did not influence ($P<0.05$) WBS; however, aging was significant ($P<0.05$). Lipid oxidation results illustrated a treatment x age interaction ($P<0.05$) with CNT and MO exhibiting oxidation at a quicker rate than IN. The inclusion of IN or MO in enhanced beef top rounds from mature cows did not negatively impact meat quality characteristics.

**Key Words:** shelf-life, beef, injection

**103 The effects of two antimicrobials on tenderness and shelf-life stability of enhanced top sirloins from mature cows.** R. M. Pitzer*, A. Ponrajan, M. A. Harrison, T. D. Pringle, B. K. Lowe, R. O. McKeith, J.R. Segers, and A. M. Stelzleni, *University of Georgia, Meat Science and Technology Center, Athens*.

The objective of this study was to analyze the effects of MOstatin™ and IONAL® (World Technology Ingredients Inc., Jefferson GA) on cow top sirloins IMPS 184B (FPL Foods LLC, Augusta GA) in cooperation with FoodPAC (Food Processing Advisory Council) of Georgia. Top Sirloins (n=60) were procured on d 3 after slaughter, and injected on d 4 to achieve a 10% pickup with 0.5% NaCl and 0.4% Sodium Tripolyphosphate in the final product for control (CNT) plus 2% MOstatin™ (MO) or 1% IONAL® (IN). Muscles were then vacuum-packaged and allowed to rest for 10 days (0°C) to mimic storage and transportation time. Objective color

(Minolta L*a*b*) and pH samples were taken before, immediately after, and 10 d after injection. After the 10 d rest period, steaks were cut (2.54 cm) and packaged (PVC overwrap) for shelf-life (SL) and stored under luminescence at 4±1° C for 7 d with objective and subjective color scores recorded daily. Subjective color was taken in 3 categories on an 8 point scale: overall acceptance (OA; 8=very acceptable, 1=unacceptable), color (COLOR; 8=light reddish-pink, 1=dark purple, brown), and discoloration (DIS; 8=no discoloration, 1=complete discoloration). Samples were taken on days 1, 7, and 14 for lipid oxidation analysis (TBARS). Steaks (2.54 cm) were also cut and aged (0°C) for Warner-Bratzler shear force (WBS) for analysis on d 10, 17, 24, and 31 post-injection. As these steaks were prepared for WBS, data for percent thaw loss (PTL), percent cook loss (PCL), cook time (CT), and endpoint temperature (TEMP) was collected. Pickup and purge data was collected.
There was a significant ($P<0.05$) decrease in L* values from before injection to 10 d after. An age x treatment interaction ($P<0.05$) was observed for both a* and b* values from before injection to 10 d after injection. There was a treatment x time interaction ($P<0.05$) for pH before, after, and 10 d after injection. L* values decreased significantly ($P<0.05$) from d 0 to d 7 of SL, however, there was no treatment or interaction effect ($P>0.05$). Values also decreased significantly ($P<0.05$) from d 0 to d 7 for a* and b*. Overall acceptance decreased ($P<0.05$) with age, but treatment had no effect ($P>0.05$). Subjective COLOR decreased ($P<0.05$) with age, while an age x treatment interaction was also observed ($P<0.05$). For DIS there was an interaction observed ($P<0.05$). There was an interaction ($P<0.05$) observed for TBARS, where IN TBARS level increased much slower over time than that of CNT and MO. Both treatments exhibited significantly ($P<0.05$) less PTL as compared to the CNT over time. The treatments also had significantly ($P<0.05$) lower PCL over time when compared to CNT. No significance ($P>0.05$) was observed for CT or TEMP. There was no significant difference ($P>0.05$) observed between age and treatment for WBS. The inclusion of MOstatin™ or IONAL® in enhancement solutions does not negatively impact the quality characteristics of cow top sirloin steaks.

**Key Words:** beef, injection, antimicrobials

**104 Antioxidative effects of inexpensive natural whey based edible film used as a coating solution for pork loin and cubed beef steaks.** S. Weerasinghe, J. B. Williams*, J. Tao, and Z. Z. Haque, *Mississippi State University, Mississippi State*.

Oxidative degradation plays a significant role in reducing shelf-life, eating quality, consumer satisfaction and subsequent loss of value to the processor, retailer, consumer and ultimately the producer. Whey, a by-product of cheese manufacturing, has a high potential to be used as a natural, healthy and abundantly available raw material for use in edible coatings for retail meat products. Based on preliminary and previous observations, the primary objective of this study was to investigate the efficacy of thermally modified (thermized) Cheddar whey in providing a barrier and antioxidative protection to pork loin (*longissimus dorsi*) and cubed (tenderized) beef steak (*semimembranosus*). These two meats were chosen because of the difference in the level of fatty acid unsaturation and because the process of making cubed meats increases the potential for oxidative degradation. Fresh Cheddar whey from the MSU Dairy Plant was skimmed using a decreaming separator and pasteurized at 71°C for 15 sec followed by batch thermization at 70°C for 0, 5, 10, and 15 min. The volume of each batch was 37.8 L and the treatments were run in

triplicate. In order to mimic the common whey protein concentrate (WPC) manufacturing practice in the U.S., the resulting batches were concentrated by vacuum evaporation (between 68-72°C) to about 30% solids, lactose seeded and stored at 7°C for 16 h to allow lactose crystallization, and then spray dried. Coating solutions for the meats were made by dissolving 5g WPC, 2.5% (w/v) sorbitol, 0.125% (w/v) $CaCl_2$, and an additional 0.25% protein, in distilled water. Solutions were degassed, heated at 90°C for 30 min., homogenized for 2 min., filtered, cooled to room temperature and the pH adjusted to 6.5 using 1N HCl, or 1N NaOH. The meat samples obtained from the MSU Meat Laboratory were cut into 1 cm cubes, briefly rinsed in distilled water, coated with the solution, drained, air dried and refrigerated (4°C) until analysis. Control samples were prepared without dipping in coating solutions. Oxidative stability was determined using TBARS and peroxide value (PV) every 24 h up to 4 days of storage at 4°C. TBARS values of beef steak samples were significantly impacted by the treatments; 5, 10, and 15 min treatments had lower ($P<0.05$) values than the control. After 4 days of storage, TBARS values of the 5, 10, and 15 min treatments decreased by 36%, 32% and 36% respectively, as compared to control. For pork loins, the 5 min treatment had lower ($P<0.05$) TBARS values and after 2 days of storage, the 5 min treatment reduced the TBARS value by 50% over the control. PVs of pork loin samples were lower ($P<0.05$) for all treatments than that of the control. Data clearly indicated that the relatively easy and safe thermization step significantly enhanced existing antioxidative properties of cheddar whey protein concentrate used as a coating solution on pork loin and cubed beef steak.

**Key Words:** beef and pork, anitoxidative, TBARS, peroxide value (PV), whey protein concentrate, thermization

## SYMPOSIA AND ORAL SESSIONS

### : Ingredient Utilization and Safety

**39 The use of lentil flour as a binder in low-fat beef burgers.** T. J. Der*[1], J. P. D. Wanasundara[2], and P. J. Shand[1], [1]*University of Saskatchewan, Saskatoon, SK, Canada*, [2]*Agriculture Agri-Food Canada*, *Saskatoon, SK, Canada*.

The incorporation of a binder into processed meat products is commonly used to create a meat matrix with enhanced texture and water holding capabilities. Lentil flour is high in protein and low in fat, and has potential application as a binder and extender in low-fat beef burgers. The objective of this study was to investigate the influence of lentil flour addition (6% or 12% levels) and micronization on cooking properties (cook yield and shrinkage), texture (shear force, texture profile analysis), color (Hunter L*, a*, b*), and sensory properties of low-fat beef burgers (10% fat). In addition, the effects of lentil type (red or green) on these parameters were evaluated. Micronized lentil was prepared by heating dehulled lentils to 135°C and grinding through a 0.1μm die-plate. The control burgers were formulated with lean beef, water, salt, and seasoning. Lentil flour was added at 6 and 12% levels to replace 6 or 12% of the meat, respectively. Some commercial binders, toasted wheat crumb (6%) and wheat flour (6%), were also incorporated in burgers as industry comparisons. Burgers were cooked in an impingement oven to an internal temperature of 75°C, and presented to 13 trained panelists for texture and flavor evaluation.

Three replications were performed on three different days. Storage of raw fresh burgers for 7 days under simulated retail display (4°C) resulted in a gradual reduction of L*, a*, b* values (darker, less red, less blue). Burgers containing micronized lentil flour displayed a slower decrease in a* (redness) than the control (no binder) and those containing non-micronized lentil. Generally, color of burgers containing 12% lentil were more blue (higher b*) and more red (higher a*) than those containing 6% lentil, 6% wheat, or control burgers. There were no differences in interior or exterior color of cooked burgers. Overall, addition of binders to a low-fat beef burger formulation increased the cooking yield and minimized shrinkage upon cooking. The use of any binder increased burger tenderness according to sensory data, which corresponded to lower instrumental hardness. Burgers with 6% lentil flour yielded juiciness and tenderness sensory scores comparable to those formulated with 6% commercial binders. Non-micronized lentil addition resulted in burgers with a higher off-flavor compared to burgers containing commercial binders. However, micronization of lentils lowered or eliminated off-flavor development in the burgers. While formulations containing 12% lentil flour displayed the highest cook yield, increased hardness and greater off-flavors were observed. There were no differences between red and green lentils as a binder in low-fat beef burgers with respect to the cooking properties, instrumental texture, or sensory properties. These results demonstrate that use of micronized lentil flour as a meat binder may offer benefits such as color stabilization for raw beef burgers, and improvement of cooking properties, texture, and flavor profiles in low-fat beef burgers.

**Key Words:** beef burger, lentil, micronization

**40 Effect of holding time on color, pH and residual nitrite of beef frankfurters formulated with either celery powder extract with pre-generated nitrite or commercially available sodium nitrite.** N. Djeri*, S. K. Williams, and J. Bacus, *University of Florida, Gainesville.*

Celery powder containing pre-generated nitrite was used in a beef frankfurter product with the intention of replacing nitrite and simulating curing characteristics. The objective of this study was to evaluate the role of holding time on the color, pH, and residual nitrite of frankfurters formulated with celery powder (CP) or modern cure (MC), stuffed into casings and allowed to set at 4 ± 1°C prior to cooking. Four beef frankfurter products were formulated using either 0.2%, 0.3%, 0.4% CP, or MC (control). Holding time was defined as the setting time from stuffing to cooking. Analyses were performed at various holding times in minutes (MIN): 20, 40, 60, 80, 100, and 120. All treatments had similar ($P > 0.05$) pH, L* and b* values. The a* values for MC were higher ($P < 0.05$) than 0.2 % CP as holding time increased. Residual Nitrite was higher ($P < 0.05$) for beef frankfurters with MC when compared to beef frankfurters with 0.2%, 0.3%, and 0.4% CP. The data revealed that beef frankfurters manufactured with MC or CP were not affected by the holding times. Therefore, no additional time would be necessary for frankfurters prepared with the celery powder prior to the cooking process. The data revealed that the holding times for frankfurters prepared with MC and CP were similar. Therefore, no additional time would be necessary for frankfurters prepared with the celery powder prior to the cooking process.

**Key Words:** pre-generated nitrite, celery powder, beef frankfurter

**41 Applications of electromagnetic, ultrasonic, or antimicrobial technology for reducing *Salmonella* and *Listeria monocytogenes* risk.** R. Y. Murphy*[1], J. A. Marcy[2], M. E. Berrang[3], and Johnsonville Sausage LLC[4], [1]*FPTI, Inc, Fayetteville*, [2]*University of Arkansas, Fayetteville*, [3]*USDA-ARS, Athens, GA*, [4]*Johnsonville Sausage, LLC, Sheboygan Falls, WI*.

Pathogenic bacteria including *Salmonella* and *Listeria* exist on food and in food processing environment, and therefore, potentially occur on finished products or in contact liquid. These bacteria compromise the safety of our food supply. The objective of this research was to reduce microbial contamination on food or in liquid without loss in quality and to develop new technologies for treating thermally sensitive foods or brine/marinate solutions. Electromagnetic, ultrasonic, or antimicrobial technology was used, respectively, in continuous systems to improve food safety of solid or liquid. A cocktail of six *Salmonella* (*S*. Montevideo, *S*. Seftenberg, *S*. Gaminara, *S*. Heidelberg, *S*. anatum, and *S*. typhimurium) and a cocktail of six *Listeria monocytogenes* were inoculated, respectively, to a level of 7-9 logs on meat or in brine. More than 3 logs of reductions were obtained for *Salmonella* and *L. monocytogenes*. The results from this study are important for all processed food industry where risk of microbial contaminations is a concern. This research offers fast, cheap, and none quality-disruptive alternatives to reduce microbial levels on food or in liquid.

**Key Words:** technology innovations, processing technology, safety and shelf-life

**42 Reduction of *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on beef surfaces and in ground beef using sequential spray application of ε-polylysine or lauric arginate followed by acidic calcium sulfate.** H. Benli*[1,2], A. Castillo[2], and J. T. Keeton[2], [1]*Çukurova University, Adana, Turkey*, [2]*Texas A&M University, College Station*.

Individual interventions in most cases are not as effective for reducing pathogens on beef carcasses as hurdle technology or a sequential interventions approach. Application of two or more microbial decontamination treatments appears to produce greater reductions than one treatment alone due to different modes of action of the antimicrobials. Acidic calcium sulfate (ACS) is a very acidic (pH 1.0 - 1.5) organic acid-calcium sulfate complex has been demonstrated to reduce pathogens on beef or poultry carcass surfaces, RTE meat products including frankfurters and hams and in ground beef. ε-Polylysine (EPL) has a wide range of antimicrobial activity and is characterized as an edible, water-soluble agent. Lauramide arginine ethyl ester (LAE) also known as lauric arginate is a surfactant with broad-spectrum antimicrobial activity. The objectives of this study were to determine effectiveness of sequentially applied warm (55 °C) solutions of (i) 300 mg/liter EPL followed by 30 % ACS (EPL300-ACS30) and (ii) 200 mg/liter LAE followed by 30 % ACS (LAE200-ACS30) for reducing rifampicin-resistant *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on inoculated beef surfaces and to determine if these reductions carried over to ground beef during refrigerated storage. Both warm (55 °C) EPL or LAE applied sequential by ACS onto inoculated beef rounds reduced ($P < 0.05$) both *Escherichia coli* O157:H7 and *Salmonella* Typhimurium counts over 0, 3 and 6 days

of storage at 4.4 °C by 2.3 to 4.3 log CFU/cm$^2$ and 2.3 to 4.5 log CFU/cm$^2$, respectively, when compared to untreated controls on each storage day. A spray application of EPL300-ACS30 resulted in an even greater reduction after 6 days of storage for both *Escherichia coli* O157:H7 and *Salmonella* Typhimurium. EPL or LAE followed by ACS were applied as a spray to inoculated beef rounds and were stored 2 days (4.4 °C) prior to grinding. Ground beef manufactured from these rounds had lower ($P < 0.05$) *Escherichia coli* O157:H7 and *Salmonella* Typhimurium counts initially and stayed lower over 4 days of storage at 4.4 °C. Reductions in counts averaged from 1.6 to 2.0 log CFU/g for *Escherichia coli* O157:H7 and 1.6 to 2.4 log CFU/g for *Salmonella* Typhimurium. Overall, these results confirmed that sequential, multi-hurdle interventions would be effective for reducing *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on beef round surfaces as well as in ground beef produced from treated beef round tissues.

**Key Words:** sequential interventions, pathogens, beef

## : Meat Composition, Quality, and Tenderness

**43 Working chute behavior of feedlot cattle can be an indication of cattle temperament and beef carcass composition and quality.** N. L. Hall*, V. L. Anderson, B. R. Ilse, K. R. Carlin, J. C. Galbreath, and E. P. Berg, *North Dakota State University, Fargo*.

The influence of temperament on beef carcass quality traits was measured on 180 mixed composition Bos Taurus steers. Steers (n = 183) were sorted into 16 different pens based on initial weight (280 kg). Steers were weighed every 28 d with data recorded for temperament as exit velocity (EV), chute score (CS), catch score (CAPS), and chute vibration (VIB). Tissue samples were collected for the commercial DNA profile by IGENITY including docility. Steers were harvested at 14 to 16 mo of age (605 kg). Measurements of hot carcass weight, ribeye area, 12th rib fat (12FD), percentage fat, kidney, pelvic, heart fat (KPH), intramuscular fat (MARB), and USDA yield grade (YG) were taken 24h postmortem. Measurements for pH (45 min and 36h) and color scores (L*, a*, and b*) were taken. *Longissimus thoracis* samples were collected and aged 14 d before Warner-Bratzler shear (WBS) force was determined. Exit velocity increased and CS, and CAPS values declined over time indicating that animals acclimated to the working chute environment. First EV had significant ($P < 0.05$) correlations with WBS ($r = -0.19$) and last EV with YG ($r = 0.19$), 12FD ($r = 0.15$), KPH ($r = 0.19$), and MARB ($r = 0.15$). First CAPS significantly ($P < 0.05$) correlated with DRESS ($r = 0.16$), 36h pH ($r = 0.30$), and L* ($r = -0.20$), last CAPS with YG ($r = -0.17$), final BW ($r = -0.15$), and pH36H ($r = 0.19$), and average CAPS with YG ($r = 0.17$), MARB ($r = -0.20$) and 36h pH ($r = 0.20$). Steers receiving a CAPS of 1 or 2 possessed more marbling (small) than steers with CAPS of 4 (slight). Ribeye steaks from steers with a slow first EV (> 1.0 sec) were more tender (3.37 kg) than steaks from fast (< 0.70 sec) and moderate (0.71 to 0.99 sec) EV steers (3.90 and 3.82 kg, respectively). However, steers with moderate to high genetic potential for docility (Igenity docility index) had tougher WBS (3.92 and 4.28 kg, respectively) than steers with low docility index (3.52 kg). These data indicate that behavior in the working chute environment may be an appropriate indicator of cattle temperament which may have a negative influence on beef palatability

**Key Words:** beef, temperament, exit velocity

**44 Meat quality of steers fed alternating high levels of distiller′s grains with solubles (DGS) in finishing diets.** J. W. Rickard*[1], B. R. Wiegand[1], D. Pompeu[1], S. W. Reader[2], R. L. Atkinson[2], P. M. Walker[3], and J. M. Carmack[3], [1]*University of Missouri, Columbia,* [2]*Southern Illinois University, Carbondale,* [3]*Illinois State University, Normal.*

The objective of this study was to evaluate the meat quality characteristics of finishing steers fed up to 70% (DM) inclusion of distiller′s grains with solubles (DGS). Also a 40% DDGS diet was compared with isocaloric and isonitrogenous diets. Ninety-six Angus steers (292±35.83 kg) were used in a completely randomized design. Steers were fed one of six treatments 1) 80% corn:5% SBM:15%corn silage (**CON**); 2) 40% DGS:45%Corn:15%Corn silage (**PCON**); 3) PCON(d0-84) switched to 70% DGS:15% Corn:15% Corn silage on d 85 until finish (**40/70**); 4) d 0-84 on 70% DGS:15% Corn: 15% Corn Silage switched to PCON d 85 until finish (**70/40**); 5) CON+SBM, isonitrogenous to PCON (**N40**); 6) CON +Corn oil, isocaloric to PCON (**E40**). Steers were slaughtered at a commercial facility in two groups at 168 and 213 d of feeding. Approximately 95% of carcasses graded within the choice classification. After 48 h chilling, a 3 rib section (rib 10-12) was taken from the longissimus, individually tagged, bagged and shipped under refrigeration to the University of Missouri Meat Science Laboratory. Rib sections were allowed to age for 7 d at 4$^{o}$ C before they were deboned, sliced into 2.54 cm steaks, and evaluated for Minolta color, Warner-Bratzler shear force (WBSF), cooking loss percentage, and total fatty acid profile. Minolta color values did not differ by treatment and ranged from 40.22 to 42.20 for L*, 24.25 to 24.73 for a*, and 10.44 to 11.08 for b*. The 40/70 steaks tended (P = 0.07) to have lower WBSF values compared with PCON steaks (2.65 kg vs. 3.12 kg). No other treatments differed for WBSF. Cooking loss percentage was similar for all treatment groups and ranged from 19.65 % to 21.58 %. We originally hypothesized that increasing the dietary oil content with DDGS might increase the flow of unsaturated fatty acids from the rumen subsequently depositing more of these fatty acids in the lipid portion of the final beef product. However, very little change occurred in the fatty acid profile when evaluated from a composite of the longissimus muscle. A significant reduction (P = 0.047) was observed for 18:3N6 in the E40 treatment compared with all other treatments. The CON tended to be lower and the N40 higher (P = 0.066) for CLA T9, T11 compared with all other treatments, but the percentages of this fatty acid overall were very small (all less than 0.11 %). No other differences were observed for fatty acid profile for any treatment group. Overall, these data indicate that DGS can be fed up to 70% DM in the finishing diet for steers without compromising meat color or shear force, and not significantly changing the fatty acid profile characteristics of the final product.

**Key Words:** beef, DGS, meat quality

**45 Assessment of slice shear force values for repeatability and accuracy on beef top loin steaks.** G. O. Clark*, J. C. Brooks, B. J. Johnson, J. D. Starkey, and M. F. Miller, *Texas Tech University, Lubbock.*

Slice shear force (SSF) values are often used in both research laboratories and in the meat

industry to determine tenderness differences between research treatments and for consumer tenderness programs. The need for SSF repeatability and accuracy across different laboratories and instruments is of the highest importance. Therefore, the objective of the present study was to determine the repeatability and accuracy and to correlate SSF values between two separate laboratories. Two beef strip top loin steaks measuring 2.54 cm in thickness were fabricated from beef strips (IMPS # 180) from a commercial beef processing facility (n = 581) and shipped frozen to each laboratory after 14 d aging. Both laboratories A and B received one steak from each animal. Steaks from laboratory A and B were cooked to an internal temperature of 71° C. A 1 cm thick, 5 cm long slice was then removed from the lateral section of the steak using the US Meat Animal Research Centers approved cutting guide and following the muscle fiber orientation. A United Testing Machine (UTM Model No. 1250) was used to obtain a SSF value from each steak immediately after cooking. Data were analyzed for accuracy indicated that there was a significant difference ($P < .0001$) in the mean SSF value between the two laboratories. The mean SSF value for laboratory A was 14.7 kg whereas the mean SSF value for laboratory B was 16.5 kg. The correlation for SSF between laboratories A and B were 0.62710 with a coefficient of determination of 37% ($P < 0.001$). Both laboratories showed an increase in SSF values within the steaks. However, the average SSF values from laboratory B were significantly ($P < .0001$) higher. The differences between labs for the actual SSF number had no effect on ranking the steaks in the same order for their SSF value. Thus, SSF can be conducted in two separate locations and accurately determine the level of tenderness and treatment differences among steaks.

**Key Words:** beef, instruments, repeatability

**46 Effect of marination on the tenderness of broiler breast fillets deboned at various times.** V. A. Kuttappan*[1], C. M. Komiyama[2], V. B. Brewer[1], J. F. Meullenet[1], and C. M. Owens[1], [1]*University of Arkansas, Fayetteville,* [2]*UNESP - São Paulo State University, Botucatu, SP, Brazil.*

Pre-rigor deboning of broiler breast meat can cause toughening of the meat. Therefore, it has been recommended that carcasses be aged 4-6 h postmortem (PM) to prevent toughening. However, some processors are deboning as early at 2 h PM in order to better streamline production. Marination is commonly used in the industry to enhance meat quality attributes and increase yield. The objective of this study was to assess the effects of marination on the tenderness of broiler breast fillets deboned at various times. Two hundred forty broilers, 6 weeks of age, were processed in two replications using standard commercial practices. Carcasses were chilled for 90 min to an internal temperature of <4°C and aged on ice until time of deboning. Breast (*Pectoralis major*) fillets were harvested at 2, 2.5, 3, 4, 6 and 8 h postmortem and aged on ice until further analysis. The pH of the meat was evaluated immediately after each deboning time. Right fillets were tumble marinated for 20 min in two replications at 24 h PM with 15% marinade solution with a final concentration of 0.5% NaCl and 0.45% phosphate. Left fillets were the control treatment (non-marinated). Fillets were cooked at 24 h PM to an internal temperature of 76°C. Marination pickup (%), cooking loss (%) and Muellenet-Owens Razor Shear (MORS) energy was evaluated. There was a significant ($P<0.05$) decrease in the pH as the deboning time increased as expected. There were no significant differences ($P>0.05$) in

marination pickup among the deboning time treatments. Overall, marinated fillets had lower cook loss than non-marinated fillets. As deboning time increased, the cook loss significantly ($P<0.05$) decreased in the non-marinated fillets, but there were no differences ($P>0.05$) in cook loss of the marinated fillets due to deboning time. Tenderness significantly ($P<0.05$) improved (decreasing MORS energy) as aging time increased in both marinated and non-marinated fillets. Marination improved tenderness as indicated by the marinated fillets having significantly ($P<0.05$) lower MORS energy values compared to non-marinated fillets at each deboning time. Furthermore, deboning at 2.5 h PM or after followed by marination resulted in similar MORS energy as deboning at 4 or 8 h PM without marination. The results indicate that marination improves tenderness of broiler breast meat and that aging periods can be shortened without negatively affecting tenderness if product is marinated.

**Key Words:** tenderness, marination, poultry meat

**105 Effect of cooking method on semimembranosus fat cells in goat and lamb muscles.**

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Fat cell distribution in the structure of semimembranosus muscle of goat and lamb was studied. Four treatments, raw (control), conventional heating, domestic, and industrial microwave heating, were observed using fluorescence light microscopy. The temperature used in conventional heating was 163 degree C. Frequency applied for microwave heating was 2450 MHz with two wattages levels of 700 (domestic microwave) and 12000 (industrial microwave). All samples were heated to internal temperature of 70 degree C. The method used here was roasting in a conventional oven and microwave heating. The advantage of roasting to other cooking methods (broiling and braising) is greater fat retention in semimembranosus muscle. Fat distribution was altered by using various heat treatments such as conventional and microwave cooking. In contrast to conventional heating systems, microwave penetrates a food and heating extends within the entire food materials and the rate of heating is therefore more rapid. Microwaves generate heat due to their interactions with the food materials. Uneven distribution of fat in the muscle system influenced fat losses during cooking and the fat cells which are located in the interior of muscle, will be lost more slowly compared to the fat cells located near the surface of muscle. During microwave cookery overall migration of fat globules or fat cells is higher than conventional cooking and also loss of fat content could also be occurring.

**Key Words**: fat cells, conventional heating, microwave heating, semimembranosus muscle, fluorescence microscopy, structure of lamb and goat