**W4177: Enhancing the Competitiveness and Value of U.S. Beef**

**Annual Report**

This annual report was compiled from station reports submitted to the current leadership of the W4177 before the annual meeting.

**1. Accomplishments**

**California – Oltjen**: Beef production can be improved with more accurate predictions of animal growth and carcass composition. Efficiency of production studies have been published, as well as models for ruminant animal’s environmental footprint.

**Colorado – Belk and Nair:** Colorado State University (CSU) has been actively engaged in several research projects during the past year focusing on palatability, processing, marketing of beef, prevention of food-borne illness, and consumer preferences for beef. We have completed a beef flavor audit to create a base line for flavor of different beef cuts using consumer sensory panels and Rapid Evaporative Ionization Mass Spectrometry (REIMS). Moreover, the suitability of new technologies to measure meat color such as Nix colorimeter was evaluated. Additionally, research examining the effect of different withdrawal period on ractopamine residues in target and non-target tissues was undertaken.

**Idaho – Bass and Colle:** Beef meat science faculty efforts at the University of Idaho have been conducting research through the past year with focus on beef tenderness, color, postmortem enzymatic activity, commercially available genetic prediction tests, and dry aging. Focus has been on heavy weight carcasses and the effect of those carcasses on the merchandising of beef round cuts. Research has been conducted on beef chuck rolls and short ribs with the introduction of rosemary extract and acerola cherry powder as topical antioxidants to improve color stability in a retail setting. Research with regard to commercially available genetic tests was completed to investigate the predictiveness of such tests on beef palatability. Additionally, some focus is underway looking more into how electrical stimulation of beef carcasses effects calpain activity. Finally, research into commercial dry aged beef facilities were investigated for palatability differences amongst microbiomes.

**Indiana – Kim:** Dr. Brad Kim at Purdue University has been working on determining the impacts of post-harvest processing factors (developing “Smart Aging”, in particular) on meat quality attributes. Beef from cull cows has been traditionally perceived as low-quality/low-value meat due to inferior flavor and tenderness. The ultimate goal of our research program is to establish novel meat aging processes that can be applied to improve quality attributes of cull cow beef and foster the profitability and sustainability of the beef industry. Our central hypothesis is that, through application of optimal dry-aging, the palatability attributes of meat will be significantly improved via the liberation of flavor-related compounds. For the current reporting period, two research objectives have been conducted: Objective 1 - Determine the impact of optimized dry-aging on physicochemical, microbiological shelf-life, and sensory eating quality attributes of loins from cull cow beef; Objective 2: Identify flavor-related chemical compounds that positively impact meat quality attributes of dry-aged loins from cull cow using a metabolomics approach coupled with other chemical assays and descriptive sensory analysis.

**Kansas – Tonsor and Chao:** Collaborating faculty completed projects with the U.S. beef industry including launching of the Meat Demand Monitor which is funded in-part by the Beef Checkoff. Other projects include ongoing work on livestock disease, biosecurity economics; examining how fed cattle negotiated prices are reported.

Additional research focused on beef tenderness. Research has been conducted on investigating the contribution of tenderness factors associated with actomyosin effect, background effect and bulk density/lubrication effect using 11 different beef cuts. In addition, research was conducted to understand Asian consumers’ purchasing preference for 6 different beef shin/shank cuts, and these shin/shanks were used as a model to understand the contribution of mature collagen crosslinks to beef tenderness. Furthermore, research with regard to investigating collagen degradation and collage crosslink break down during extended postmortem aging is underway.

**Kentucky – Suman:** Vitamin E is a lipid-soluble antioxidant that can inhibit lipid oxidation and improve beef color stability. The effect of vitamin E on fresh beef color, from the standpoint of lipid oxidation-induced myoglobin oxidation, has been extensively studied. However, the influence of vitamin E on sarcoplasmic proteome profile of beef skeletal muscles is yet to be investigated. Therefore, the objective of this study was to examine the effect of dietary vitamin E on sarcoplasmic proteome of postmortem beef longissimus lumborum (LL) muscle. Crossbred heifers, managed with a GrowSafe feeding system, were fed ad libitum corn-based diet containing either no supplemental (CONT) or 1,000 IU vitamin E/heifer per day (VITE) for 89 days. The animals were harvested, and carcasses were chilled. The LL muscle samples were obtained from the carcasses of nine (n = 9) VITE and nine (n = 9) CONT heifers 24 h postmortem. The muscle samples were individually vacuum-packaged and frozen at -80°C for proteome analysis. Sarcoplasmic proteome was analyzed using two-dimensional electrophoresis, employing immobilized pH gradient strips (pH 3-10; 17 cm) in the first dimension and 12% sodium dodecyl sulfate polyacrylamide gel electrophoresis in the second dimension. The gels were scanned, and the digital gel images were analyzed. The protein spots exhibiting more than 1.5-fold intensity differences (P < 0.10) between VITE and CONT were subjected to in-gel tryptic digestion and were identified by tandem mass spectrometry. Five differentially abundant spots were identified using mass spectrometry, and all the spots were over-abundant in CONT. The proteins in the differentially abundant spots were antioxidant proteins (thioredoxin-dependent peroxide reductase, peroxiredoxin-6, and serum albumin) and glycolytic enzymes (beta-enolase and triosephosphate isomerase). The antioxidant proteins minimize oxidation of lipids and proteins in muscle matrix, whereas the glycolytic enzymes generate NADH, which helps maintain the antioxidant proteins in their reduced forms. The strong antioxidant protection offered by vitamin E could have possibly led to low expression of antioxidant proteins as well as glycolytic enzymes that generate antioxidant metabolites in the VITE group, whereas the lack of such protection in CONT group may have led to increased expression of these proteins in the skeletal muscles.

**Michigan – McKendree:** Dr. McKendree has been working on evaluating the impact of changing domestic retail beef demand and export beef demand on different sectors of the US beef industry. Another project examines what motivates beef producer’s current management practices to understand why BMP adoption in the beef industry has been low. Understanding BMP adoption has implications for consumer perceptions of beef production, animal health, and supply chain management.

**Mississippi – Dinh**: We established that natural antioxidants rich in vitamin C was best to protect lean color of grass-finished beef steaks. We also determined that pre-rigor beef sausage has greater consumer acceptability and demand than post-rigor beef sausage. To study oxidative stress in beef cattle, we established dosage of hydrogen peroxide to induce oxidative stress in beef cattle. We completed a time-course study and identified sampling time point for oxidative stress markers. We also completed the study on the effects of feeding endophyte-infected tall fescue seeds on beef quality.

**Montana – Yeoman:** Our findings that several microbial taxa show strong correlative relationships to animal productivity and immunological development have led to funded efforts to experimentally interrogate these relationships. In recently published studies, we have identified that the physical structure of feed and form of mineral supplementation influence ruminal microbial composition. Finally, in on-going studies we are finding that select wild ruminant species (antelope, deer, elk, mountain goat, bighorn sheep, bison) harbor rumen microbial communities that can degrade toxic alkaloids in tall larkspur (*Delphinium occidentale*) – a common range plant in the Mountainous West that causes significant annual mortality among range cattle.

**North Dakota – Maddock:** Two projects reached final completion and one project was initiated examining beef quality.

Research investigating production systems on beef quality was completed by finishing data analysis and manuscript preparation. This project measured the tenderness and sensory qualities of steaks from steers that had been growth under various production systems including grazing of native pasture, grazing forage crops including forage corn. All steers were finished using a typical feedlot diet and then slaughtered at a commercial packing plant. United States beef production systems vary greatly among regions and evaluating how different systems affect beef quality is essential to ensuring U.S. beef is competitive in the global market.

The second completed project investigated the relationship among carcass weight, postmortem metabolism, and beef quality with the carcass and meat quality outcomes presented at our previous meeting. For this project we continued to perform analysis of postmortem protein degradation. Muscle samples from the longissimus and semimembranosus were collected at d-3 and d-14. Western blots for Troponin-T (TnT) and heat shock protein 70 (HSP70) were performed on d-3 and d-14 LD, and d-3 SM. By understanding if carcass weights affect postmortem metabolism, we increase our understanding of factors that affect tenderness of beef.

A project was initiated examining consumer preference for size and shape of various beef steaks. A retail partner was found, and various steaks were evaluated at retail cutting and display for size, shape, weight and color. Steaks were monitored in the retail case to determine how quickly they were bought. This project was initiated in late summer and suspended until early summer 2020 when steaks are bought at higher volume. Understanding consumer preference for size and shape of beef steaks can provide beef marketers with an increased understanding of consumer preferences.

**Nebraska – Calkins and Sullivan:** Calkins has collaborative research with Mississippi and Texas A&M University. Continued collaborations are planned. Fresh meat research has focused on three main areas. These are the relationship of oxidative stress to meat tenderness, frozen meat color, and dry aging. Research on oxidative stress and dry aging has been funded by the Nebraska Beef Council. Sullivan has focused on safety and spoilage of beef products. Additional work has been conducted to understand the color change in raw beef caused by high pressure processing.

**Nevada – De Mello**: De Mello’s research approach three major areas including food safety, meat quality attributes, and meat consumption and health. De Mello’s food safety research focuses on improving robust food safety systems of meat processing plants by optimizing the utilization of antimicrobials with a special focus on the application of bacteriophages to control Salmonella and STEC. Currently, the major goal is to elucidate how bacteria develops antimicrobial resistance after being exposed to phages. Regarding meat quality, research has been conducted to evaluate the effects of animal feeding on epigenetic effects associated to gene expressions that may alter tenderness and adipocyte development. A study involving feeding veal calves with brewery byproducts and Omega 3 oils were also conducted to evaluate the effects of those feedstuffs on animal welfare, growth development, carcass characteristics, fat and fatty acid contents, flavor, and tenderness. For fresh beef, incorporation of condensed tannins in ground beef was evaluated as a measure to extend shelf life. Extensive dry-aging studies were also conducted to understand the role of USDA grade, volatiles and amino acids on flavor development. Preliminary research to evaluate the survivability of beef-derived microRNAs after cooking was conducted. For the meat consumption and human health area, de Mello will study the interactions of beef miRs with intestinal epithelial cells and gut microbiota to further investigate possible correlations with colorectal cancer, diabetes, and obesity.

**Tennessee – Thompson, Myer, and Kojima:** Basic and applied research was conducted to examine

* Willingness to pay to invest in biosecurity related to feedlot disposal capacity
* The effects of animal health events on agribusiness firm values
* The adoption of biosecurity practices and the impacts on business continuity during disease outbreaks
* The effects of farm practices on international trade relationships with korea
* The economic costs of control for bovine leukemia virus
* The microbial populations and associated changes within the gut as a function of varying feed efficiency phenotypes
* Metabolomes from cattle divergent in feed efficiency
* Production effects on the rumen microbiome
* Temporal stability of the ruminal bacterial communities in beef steers
* A review on microbiomes in ruminant protein production and food security
* Understanding the impact of the rumen microbiome on beef cattle performance
* Rumen fluid metabolites associated with feed efficiency in angus steers
* Effects of rumen content exchange on bacterial community dynamics and production-relevant parameters
* Effect of stocking density on ruminal bacterial communities of holstein dairy cows
* A 16s rdna reference database of the deep-nasopharynx in steers for bacterial community analysis of cattle with bovine respiratory disease complex
* Rumen and serum metabolomes differ in angus cows
* The effects of a moderate and aggressive implant strategy on the ruminal microbial community and metabolome in steers
* Rumen fluid metabolomics of beef steers differing in feed efficiency
* Rumen bacteria and serum metabolites predictive of feed efficiency phenotypes in beef cattle

Projects from this station were highlighted in a special report issued by the Supporters of Agricultural Research (SoAR) Foundation and 20 FedByScience Universities which highlighted the most important fields to advance in animal agriculture by the year 2030 (https://supportagresearch.org/assets/pdf/retaking-the-field-vol-4.pdf ). These areas were determined by the National Academies of Sciences, Engineering, and Medicine (NASEM) as part of a widespread scientific effort to prioritize agricultural research endeavors.

These efforts also contributed training and professional development. Analyses were presented at multiple meetings. This work was used to support and develop four graduate students through economic modeling, laboratory/bench research, light bioinformatics, physical sampling and animal handling, data and statistical analyses, and research manuscript preparation.

These station activities facilitated the collaboration between Zamorano University and the University of Tennessee Institute of Agriculture. Zamorano is an international agriculture-centric university in Honduras that focuses on addressing challenges in Latin America; such as conservation of natural resources, rural transformation, and development of internationally competitive agricultural and agro-industries. In the past year, station participants hosted two interns from Zamorano University as part of the internship program. Future research collaborations and UTIA graduate students are anticipated. Educationally and professionally, this collaboration has and will continue to result in the education and training of future food and animal scientists and workforce, with a gained understanding and appreciation of the importance of sustainable agriculture and food safety. This program has and will continue to develop effective teaching techniques that meet the needs of a wide range of students of varying demographics.

Project output was used in multiple courses, extension programs, research centers, and public outreaches. Outreach activities were undertaken to reach children interested in science who are not usually aware of these research activities and to increase their interest in science. This was conducted at the elementary level via several 1-hour "Meet the Expert" sessions for 5th-grade students in Knoxville, TN on science experiments in biology and animal science, and career opportunities in science and agriculture.

These activities are in line with supporting a better understanding of beef production, health, and biosecurity to support the competitiveness and value of U.S. Beef. The analyses discussed below have increased the knowledge base of master students, industry professional, producers, government policy makers, and academics. The projects impact reached multiple national and international audiences including Egypt, Ethiopia, Japan, Korea, and United Kingdom to name a few. The results from these analyses were used to create peer-reviewed manuscripts and were presented at academic conferences. Manuscripts were also disseminated to policy makers and co-collaborators at USDA agencies. These analyses have been presented across multiple national and international conferences of academics, professionals, government agencies in multiple disciplines including economics, veterinary sciences, and social sciences.

**2. Short-term Outcomes**

**California – Oltjen**: Developing collaborations and journal articles.

**Colorado – Belk and Nair:** The beef flavor audit created a baseline of flavor associated with several beef cuts. The sensory analysis was followed up by REIMS analysis to evaluate the capability of the machine to distinguish flavor attributes in different beef cuts. The results from the comparison of Nix with HunterLab colorimeter indicated that Nix could be a viable alternative for measuring meat color.

**Idaho – Bass and Colle:** The deep portion of the top round of larger carcasses takes longer to chill and therefore has a more rapid pH decline. This negatively affects the shelf-life of the top round. Regardless of carcass size, the deep portion of the top round has poorer color stability and is tougher than the superficial portion of the top round. Dry aging microbiome work has been delayed due to COVID-19, however, yield and palatability has been shown to be different among commercial dry-aging facilities. Commercial genetic testing has shown to be effective at predicting carcass traits on crossbred commercial beef cattle. Low-voltage electrical stimulation has shown to be not effective at stimulating an increased response in calpain activity. Rosemary extract and acerola cherry powder are effective antioxidants for extending the color stability of beef chuck rolls and short ribs.

**Indiana – Kim:** The results indicated that conventional dry-aging would not negatively affect the shear force, cooking loss as well as oxidative stability of loins collected from mature beef loins. Trained panelists also indicated less sour and oxidized flavor in dry-aging compared to wet-aged counterparts, showing its potential to improve mature beef loins. These improvements, along with good color stability suggested the potential of dry-aging as a natural value adding process for merchandizing cull cow beef. The UV light application significantly reduced the microbial concentration of the dry-aged beef crust, but an increase in oxidized flavor was found. The dry-aging treatments were observed to have greater amino acids and sulfur containing compounds, while more lipid related compounds were observed in wet-aged counterparts. This result potentially indicates that the major mechanism of flavor production would be different depending on the aging method applied. Further research correlating these compounds to descriptive sensory quality attributes is currently underway.

**Kansas – Tonsor and Chao:** A better, deeper understanding of U.S. beef demand strength, determinants, and impact on cattle producers.

Furthermore, results from our studies showed that each muscle has specific tenderness factors that contributed to the overall tenderness evaluated by trained panelists. Only total collagen content may be causally used as an overall tenderness predictor, and tenderness improvement techniques need to be developed for each individual retail cut based on its specific properties. On the other hand, we identified 2 specific beef shin/shank cuts that Asian consumers preferred over the other shin/shank muscles using moist heat cookery, providing value-added opportunities in the export market. Finally, we confirmed that mature collagen crosslink densities can be used as a strong marker to predict cooked beef tenderness in beef cuts with greater collagen content.

**Kentucky – Suman:** Data from the project indicated that the strong antioxidant protection offered by dietary vitamin E in beef cattle could possibly lead to low expression of antioxidant proteins as well as glycolytic enzymes in longissimus lumborum muscle.

**Mississippi – Dinh**: Natural antioxidants rich in vitamin C is most effective at protecting lean color of grass-finished beef steaks and when being used for spraying technique. Moreover, the greater consumer acceptability of pre-rigor sausage is driven by flavor and texture acceptability. The combination of cost effectiveness with an increase in demand in the current study, pre-rigor beef sausage technology warrants further analysis as an economically viable alternative to post-rigor production technology in the United States. The feeding of endophyte-infected tall fescue seeds with a long withdrawal period during the stocker phase of beef cattle production will have minimal impacts on beef quality attributes during retail display. The supplementation of alfalfa, a known source of vitamin E might have minimized the negative impacts of ergovaline in infected tall fescue seeds.

**Michigan – McKendree:** Despite its importance in many decisions throughout agriculture, limited empirical work has quantified how changes in primary demand impact producers operating at different levels of vertically-connected industries. A structural system of equations was estimated to quantify the impacts of U.S. retail and export beef demand on fed and feeder cattle demand and supply. Increases in retail and export demand positively impact both feeder and fed cattle producers. The estimated transmission elasticities suggest shifts in retail and export demand, whether positive or negative, accrue proportionally more to feeder cattle producers than fed cattle producers. Using estimates from previous literature of the effect of generic advertising on beef demand, simulation results suggest feeder and fed cattle producers would benefit from increasing beef checkoff assessments from $1 to $2. Furthermore, an increase in export demand of more than 3.5% from observed values would cover aggregate costs of implementing source and age verification. While primary suppliers are often not directly involved in primary demand activities in vertically-connected industries, this study highlights the key economic value for primary suppliers to support demand enhancing activities.

**North Dakota – Maddock:** For the first project, we found that steers grown under various production systems produced carcasses with similar quality and yield traits with no detectable differences in shear force or sensory traits. There are multiple production systems that can be used to produce beef that is acceptable in quality and palatability traits, and livestock producers can utilize systems that provide the best potential for economic gains without adversely affecting meat quality.

For the second project we found HSP70 protein was not influenced by carcass size but were different between muscle types. Troponin-T degradation was influenced by carcass size in the SM but not the LD. However, in the LD, correlations between the 30 kDa TnT band and carcass size as well as ribeye area were negative indicating that the LD would have less protein degradation as the carcasses got larger. However, in the SM, there was an opposite observation where the larger carcasses had more 30 kDa TnT degradation product. Based on the correlation data, these differences do not seem to be temperature or pH dependent. However, the LD and SM respond differently to increases in carcass size with regard to protein degradation during aging.

The third project is ongoing.

**Nebraska – Calkins and Sullivan:** Results of research on frozen meat color have been used to provide advice directly to the meat industry. Presentations about dry-aged beef made to meat industry, students, and faculty in Brazil. Increased understanding of beef spoilage was discussed with industry participants during the global processing workshop. Impacts of high pressure processing on beef color was presented to the HPP workshop hosted by the Food Processing Center.

**Nevada – De Mello:** Food safety - Bacteriophage applications are more efficient than the most common antimicrobial solutions currently used by the beef industry. Phages provide superior control of Salmonella and STEC when compared to PAA, LA, and ASC. When targeting STEC, phages are also efficient against the “Big Six” STEC and not only against the O157:H7. The industry was advised about the efficiency of current antimicrobials. Preliminary data showed that bacteria may differentiate after being exposed to phage. Further investigations are needed. Meat Quality – Initial studies were conducted to evaluate the expression of genes that modulate the calpain/calpastatin, caspase, lysosomal, and proteasome systems during enzymatic tenderization. No results were obtained yet but this data will provide precise information about tenderness biomarkers based on which stage of enzymatic tenderization beef is. Feeding omega 3 and maize starch decreased cortisol of calves. Feeding the oil source of omega 3 increased the levels of EPA and DHA in the lean. Overall, American veal may be produced with superior quality than veal imported from overseas. The incorporation of condensed tannins improved lipid stability of ground beef. However, levels up to 0.5% DM inclusion may lead to detrimental effects on color and flavor. The industry must be careful when using this source of antioxidants. Dry-aging seems to not be the major factor that affect flavor but fat content and fatty acid profile. When evaluating dry x wet aging in a factorial with USDA Select and Choice, Grade seems to play the most important role on flavor development. The amino acid profile is primarily affected by aging length. Dry aging may affect volatile profile when interacting with USDA grade. Meat Consumption and Health – Preliminary results showed that microRNAs (miRs) survive through cooking and are available for interactions with gut cells and may possibly shape the microbiota. De Mello future research will investigate the crosstalk between exogenous miRs, gut cells, and microbiota.

**Tennessee – Thompson, Myer, and Kojima:**

Economic Project Outcomes

On a farm, producers choose how to dispose of carcasses in whatever way they decide given the parameters of the environmental laws they are subjected. This includes on-farm and off-farm practices such as rendering. In the case of animal disease events there can movement restrictions even for non-infected farms which can inhibit the disposal of everyday mortality if they use off-farm means. Over the past year under this project, in collaboration with other multistate project participants we analyzed survey data of poultry producers regarding their willingness to pay for additional disposal capacity as a means of increased biosecurity measure and how they ranked indemnity policy. To accomplishment this facet of the overall goal of this project, an estimate of poultry producers' willingness to preemptively invest in disposal capacity that would allow them to better continuity of business during a highly infectious disease outbreak and how much they were willing to invest was estimated to be a $29 thousand. This was compared with previous years analysis of feedlot willingness to pay ($14 thousand) in order to better understand the a more complete livestock production view of biosecurity. Additionally, using the survey, and estimate of indemnity preference across feedlot and poultry producers was estimated, with the most preferable to use market values and the second would be for the government to subsidize biosecurity adoption.

Disease outbreak affect the value and profitability of firms. Using poultry diseases (due to their occurrence in the US) as a parallel, we found that firms were significantly impacted during a disease event. We estimated the windows in which were more likely to have a significant change in firm value. This also provided a basis for understanding the heterogeneity of firms and its impact on the rate at which a disease will impact the firm.

In understanding how biosecurity adoption can influence business continuity. An analysis of a highly pathogenic disease in Minnesota was estimated with and without predetermined permitting process. This analysis found that plans which allow movement of non-infected animals during a disease outbreak has substantial benefits to producers and consumers. The benefits of allowing negligible risk products to move far outweigh the potential costs.

In support of the goal to understand how biosecurity can influence beef market access abroad, an analysis of the Korean-US trade agreement was estimated to understand, after the adoption of practices and procedures lined out in the agreement, the value of the market and habit formation in Korea for US beef products. We found that there is substantial value to entering in the market and creating habitual consumers in Korea.

To understand the effects of biosecurity on farm, I helped collaborate with Canadian researchers in estimating the economic costs of Bovine Leukemia Virus Control. We found that it is not profitable to adapt every measure of control, but that testing and culling for the disease was the best fit after accounting for uncertainty.

Regarding Ruminant Health Projects

The global human population is expected to exceed almost 10 billion by the year 2050. In order to sustain such population growth, global demand will require 70 percent more food, creating a 50 percent increase in the demand for beef and dairy products on existing resources. In this context, such increases will have to come from efficiency-enhancing technologies, and current livestock systems will need to progress towards improving the efficiency of feed utilization in ruminants in order to improve the safety, value, competitiveness, and domestic and international marketability of U.S. beef products. Regarding beef cattle, the ability to approach such advances requires examination of the nutritional status of the ruminant, which is influenced by many factors, including diet, management, host genetics, and the diverse symbiotic microbiota colonizing the gastrointestinal tract (GIT). The GIT of cattle contains a diverse microbial community that aids in digestion by fermentation of the feed. In turn, the fermentation products of the microbial community dictate the nutrient profile that the animal receives. With advances in high-throughput sequencing technologies, researchers have been able to interrogate specific microbial communities at great depth, revealing significant differences within these communities that would not otherwise be detectable using culture-based methodologies. This has enabled the enhanced study of the structure and function of the ruminal and GIT microbial communities and their associations with nutritional and management parameters. In order to dissect the microbiological mechanisms explaining differences in cow/calf feed efficiency, we have focused on using a microbiome/metagenomic approach within the rumen and lower GIT of beef cattle to develop insights into the association of management strategies, nutritional inputs, and ultimately feed efficiency with shifts in microbial populations, microbial gene expression, and digestion/fermentation. In summary, this project is focused on elucidating the molecular and microbiological mechanisms involved in the efficiency of feed utilization with the intent to focus on beef value at all levels of production. This multi-disciplinary approach to investigate food safety, food security, and beef production sustainability permits the evaluation of production-level impacts on the competitiveness and value of U.S. Beef. This station has studied a) the microbial populations and associated changes within the gut as a function of varying feed efficiency phenotypes, b) metabolomes from cattle divergent in feed efficiency and c) production effects on the rumen microbiome.

**3. Outputs**

**California – Oltjen**: Four journal articles have been published in scientific journals

**Colorado – Belk and Nair:** Six manuscripts and four abstracts were published. Three talks were given. Also, 3 M.S .and 1 Ph.D. students were graduated during the past year

**Idaho – Bass and Colle:** Idaho published 5 peer-reviewed manuscripts, 1 review paper, and 5 abstracts. Additionally, Drs. Bass and Colle were frequently invited speakers at state and regional events. Furthermore, 2 graduate students from the lab completed their M.S. Degrees and 5 undergraduate students completed their B.S. Degrees

**Indiana – Kim:**

* Published several peer-reviewed articles and presented research abstracts/proceeding papers.
* Served as invited speaker at national scientific meetings and AMSA Special Webinar.
* Trained 3 Phd and 1 MS student, 4 visiting scholars and 2 undergraduate students for their research projects.

**Kansas – Tonsor and Chao:** Michael Chao published 1 article in a peer-reviewed journal, 3 abstracts from professional meetings, and graduating 1 M.S. student.

A more complete list of publications is at the end of this document.

**Kentucky – Suman:**

1. Dr. Surendranath Suman received the American Meat Science Association International Lectureship Award (2019).
2. Dr. Surendranath Suman delivered invited presentation on fresh meat color stability at the American Meat Science Association Annual Reciprocal Meat Conference (Fort Collins, CO, June 2019).
3. Results were presented as posters at the American Meat Science Association Annual Reciprocal Meat Conference (Fort Collins, CO, June 2019).
4. Yifei Wang (M.S. student under the supervision of Dr. Surendranath Suman in the project) received First Place in the Proposal Division at the Annual Poster Symposium of the Animal and Food Sciences Graduate Association, University of Kentucky.

**Michigan – McKendree:** One seminar, four seminars, and one popular press.

**Mississippi – Dinh**: 2 journal articles, 4 abstract, 2 undergraduate research scholars, graduating 1 PhD student.

**Montana – Yeoman:**

* Six manuscripts were published as outlined below.
* Shown physical characteristics of feed alters rumen microbial characteristics
* Shown differing forms of zinc supplementation have differing effects on rumen microbiota
* Identification of microbial taxa associated with subclinical mastitis
* Invited speaker for the Animal Microbiomes session at the 18th meeting of the International Society of Microbial Ecology (ISME) in Cape Town, South Africa (postponed until 2021).

**North Dakota – Maddock:** Manuscripts for the first two projects have been prepared and submitted to Applied Animal Science and Meat and Muscle biology respectively.

**Nebraska – Calkins and Sullivan:** Calkins has published 7 articles in peer-reviewed journals, 7 in other peer-reviewed venues, and 12 abstracts from professional meetings. In addition, 23 science-based presentations about beef were given to national and international audiences. Related to W4177, Sullivan published 1 meeting abstract, advisor for 1 Ph.D. dissertation, and presented 7 science-based presentations about beef to state, national, or international audiences. In addition, we have 3 abstracts submitted to the International Congress of Meat Science and Technology related to this research from this project.

**Nevada – De Mello:** 3 journal articles**,** 3 abstracts**,** 2conference proceedings,1 technicalreport, 1 invited presentation.

**Tennessee – Thompson, Myer, and Kojima:** 9 journal articles, 14 conference abstracts,

**4. Activities**

**California – Oltjen**: *None*

**Colorado – Belk and Nair:** The following activities were taken up by the PIs (Keith Belk and Mahesh Nair) for knowledge dissemination.

1. Hosted large workshops to discuss industry issues and present research findings.
2. Served as invited speakers at scientific meetings to present research.
3. Served as members of advisory boards for research foundations.
4. Integrated research findings into university courses and curriculum.
5. Published numerous peer-reviewed articles

**Idaho – Bass and Colle:** Hands on meat lab and research lab training were provided to 5 graduate and 12 undergraduate students in Meat Science.

**Indiana – Kim:** Dr. Brad Kim was invited to give keynote presentations at the concurrent session (Metabolomics Approach to Improve Meat Quality and Value) and the technical session for dry-aging at the last year RMC meeting. Dr. Kim also presented a poster and oral session at the International Congress of Meat Science and Technology, Berlin, Germany. Dr. Kim also gave a AMSA Special Webinar Invited presentation entitled "Dry- aging beef: Bridging the gap between science and art". Some of the results of the current project were also disseminated through online media coverage such as American Association of Meat Processors and Meatingplace, The doctoral students (Derico Setyabrata and Siwen Xue) attended national meetings (Reciprocal Meat Conference; RMC) to present some of findings of the current study and to participate in the graduate research competition in the PhD division. Dr. Kim is currently serving as a co-chair of 2020 ICoMST/RMC Program Abstract Committee.

**Kansas – Tonsor and Chao**: Some example meetings where knowledge was shared with livestock producers, policy makers, or other industry stakeholders includes International Meat Secretariat Economics Workshop in Argentina, USMEF Strategic Planning Conference, US House of Representatives Staff Hill Briefing, ASAS Annual Meeting, Senate Ag Staff Briefing, and KSU Cattlemen’s Day.

Multiple research projects were conducts investigating the basic mechanism affecting beef tenderness. These projects trained 3 graduate students. Michael Chao was invited to present research results at various venue including Kansas Cattleman’s Association Annual Convention, Kansas State University Cattleman’s Day, and Mexican Short Course.

**Kentucky – Suman:**

1. Research training was provided to Shuting Li and Yifei Wang on muscle proteome isolation, spectrophotometry, two-dimensional electrophoresis, gel image analyses, analyses of mass spectra, and evaluation of meat color stability.
2. Results were presented as posters at the American Meat Science Association Annual Reciprocal Meat Conference (Fort Collins, CO, June 2019).

**Michigan – McKendree:** Research on beef demand was published in a peer-reviewed journal in conjunction with collaborators at Kansas State University. This research was presented to multiple beef stakeholder audiences. Findings suggest that all cattle producers are positively impacted by increased domestic and export beef demand. However, feeder cattle producers benefit proportionally more than fed cattle producers.

Beef producers have heterogeneous motivations for their current set of management practices. The most important motivations for the majority of producers were caring for the land, passing on the land, and minimizing risk.

**Mississippi – Dinh**: conducting three research projects on natural antioxidants on beef steaks, oxidative stress in beef cattle, and beef quality of steers fed tall fescue seed. Results are published on journal articles and conference proceeding. We graduated one PhD student and complete mentorship programs for two undergraduate research scholars. Two graduate students and two undergraduate students traveled to American Meat Science Association Reciprocal Meat Conference in Fort Collins and American Society of Animal Science Annual Meeting in Austin.

**Montana – Yeoman:** Research has been performed to understand the factors influencing gut microbial composition, and the role of gut microbiota in animal health, including immune development and productivity using modern molecular techniques, including DNA sequencing, metagenomics, and metabolomics.

**North Dakota – Maddock:** We are continuing projects evaluating beef steak size, shape, and weight on consumer preference in a retail setting.

**Nebraska – Calkins and Sullivan:** The committee presented a symposium session to the 2019 Reciprocal meat Conference of the American Meat Science Association, called “Enhancing the Competitiveness and Value of U.S. Beef.” Calkins participated in an international workshop on producing quality beef in Brazil and presented a discussion session about dry-aged beef at the 2019 Reciprocal Meat Conference of the American Meat Science Association. Multiple research projects were conducted on the topics of the relationship of oxidative stress to meat tenderness, frozen meat color, and dry aging. Research showed that oxidative stress of the live animal can impact subsequent meat quality. New information about the effects of relative humidity, air speed, muscle pH and blade tenderization on dry-aged beef was obtained. The impact of oxygenation level on color of frozen beef was explored. Research projects were conducted evaluating the survival and growth of *Pseudomonas* in vacuum packaged cooked beef, the control of *E. coli* in sous vide cooked steaks using different temperatures and holding times, and impacts of ingredients, packaging, and processing steps on microbial population and spoilage of processed beef items.

**Nevada – De Mello:** Developed research to optimize food safety interventions for the beef industry. Evaluated the effects of dry and wet aging on beef. Evaluated the effects of novel antioxidants as ingredients to be incorporated into ground beef, Developed research approaching cattle nutrition effects on quality attributes of beef and animal welfare. Investigated the availability of beef-derived miRs at the duodenum for further correlation with human chronic diseases. Trained 1 Ph.D., 2 M.S. and 2 B.S. students. Served as the Nevada Food Safety Task Force chair, this project’s chair, and as a member for the USDA National Advisory Committee on Meat and Poultry Inspection.

**Tennessee – Thompson, Myer, and Kojima:** Activities include research from multiple participants, presentations, invited lectures and discussions, student development, Extension outreach, teaching curriculum development, and multidisciplinary collaborations.

**5.Milestones**

**Colorado – Belk and Nair:** Multiple research projects were completed and published during the year. Additional research is underway on several aspects of red meat quality.

**Idaho – Bass and Colle:** Both completed their third-year review and are on a positive trajectory toward tenure status at the University of Idaho.

**Indiana – Kim:** Dr. Kim and his collaborators will conduct next research objective -
Objective 3: Evaluate the economic costs and benefits of dry-aging of cull cow beef on beef producers and meat/food processors incorporating supply-side and demand-side assessments. Moreover, the project team will finalize the remaining chemical analyses (e.g. volatile analysis) along with metabolomics profiling and microbiome analyses for the project. We will also work on finalizing our working manuscripts and submit these manuscripts to peer-review journals for publication.

**Kansas – Tonsor and Chao:** Multiple Research projects were completed and in the process for publication. Two projects were funded by National Cattleman’s Beef Association.

**Kentucky – Suman:** Characterized dietary vitamin E-induced changes in sarcoplasmic proteome of postmortem beef longissimus lumborum muscles.

**Michigan – McKendree:** We helped to quantify how beef producers are impacted by changing domestic and export beef demand and disseminated these results to stakeholders.

- Published peer review journal article

- Create and administer US cow-calf producer survey

- Training of one MS student

- Multiple producer and stakeholder events

**Mississippi – Dinh**: Completing the study on tall fescue seed and beef quality, collecting data and writing manuscript for natural antioxidant in beef steaks, establishing dosage for inducing oxidative stress in beef cattle. The PI has been granted tenure.

**North Dakota – Maddock:** Two projects have been completed with manuscripts submitted, and a third project has been initiated.

**Nebraska – Calkins and Sullivan:** The committee presented a symposium session called “Enhancing the Competitiveness and Value of U.S. Beef” and Calkins presented a discussion session on dry-beef aged to the 2019 Reciprocal meat Conference of the American Meat Science Association. Calkins made in invited symposium presentation to an international workshop on producing quality beef in Brazil.

Oxidative stress caused by injection of lipopolysaccharide into lamb showed strong trends to meat quality through proteomics, transcriptomics, and physical characterization. In addition, animal diet impacts color stability and shelf life.

**Nevada – De Mello:** Bacteriophages seem to be the best available processing aid to decrease the incidence of STEC and Salmonella in beef. MicroRNAs are overexpressed post mortem which may lead to late expression of genes associated to meat tenderness. USDA grade play a more important role in flavor development than dry aging. Beef-derived microRNAs are available after digestion and may modulate human health status. De Mello presented a discussion during the Enhancing the Competitiveness and Value of U.S. Beef symposium held at the 2019 Reciprocal meat Conference of the American Meat Science Association.

**Tennessee – Thompson, Myer, and Kojima:** Milestones include dissemination to multiple, disciplinary and cross-disciplinary peer-reviewed journals. An applied outreach website was produced as a result of this project. The website aims to offer the audience the opportunity to learn more about the role of the rumen and lower gut microorganisms and their impact on the host's performance and health. Monthly, this page features a microbe found in the gut of ruminants. http://rumenmicrobes.utk.edu Student internships provided professional and student development for both US students and those from Zamorano University.

**6. Impact Statements**

**Colorado – Belk and Nair:** The research undertaken at Colorado State University will improve our understanding of beef flavor. Moreover, the identification of the ractopamine residues limits in off-target tissues will help beef industry to establish standards. Validation of Nix for measuring meat color will provide an additional resource for measuring meat color.

**Idaho – Bass and Colle:** The previous and ongoing research at Idaho continues to work to improve product quality and consistency. Our main goal is always to find ways to increase beef consumption and acceptance which thereby adds value to all segments of the beef industry.

**Indiana – Brad Kim:** Dr. Kim’s research program centers around three major research objectives: 1) identify fundamental biochemical mechanisms governing meat quality attributes, such as color, tenderness, flavor, water-holding capacity and juiciness, 2) develop innovative technologies from the live animal pre-harvest to the post-harvest chain of events to improve meat quality, and 3) identify and develop novel meat or non-meat ingredients to create values from underutilized low-value sources.

**Kansas – Tonsor and Chao:** Allocation of U.S. beef industry resources are improved given the actionable knowledge that followed from the research-based assessment of U.S. beef demand strength, determinants, and impacts on producers.

Our research aims to understand different factors contributing to beef tenderness and utilize novel technology in the beef industry that can provide predictive knowledge on economic relevant meat quality traits for any beef cuts. These novel approaches will ensure the consistency of U.S. beef quality and ensure the competitiveness of US beef.

**Kentucky – Suman:** The long-term goals of this project are to improve color stability and marketability of retail U.S. fresh beef products by examining biochemical mechanisms governing beef color and developing strategies to increase shelf life. Fresh beef color is a major trait governing consumers' purchase decisions. The bright cherry-red color of fresh beef is exploited by consumers as an indicator of wholesomeness at the point-of-sale, and discolored cuts are often discarded or sold at discounted price resulting in huge economic losses. The estimated annual revenue loss for the U.S. farm economy corresponding to beef discoloration is $1 billion. Improving beef color stability will enable industry to increase marketability and maximize revenue, and ultimately contribute the competitiveness of the agricultural sector. Strategies to manipulate exogenous and endogenous factors influencing myoglobin redox stability can be readily applied to enhance beef color stability. In practical situations, these strategies are utilized as packaging and ingredient technologies in fresh beef processing.

**Mississippi – Dinh**: The research conducted by the PI provides solutions for the beef industry to improve beef shelf life and eating experience. The research on oxidative stress will fill the gap in knowledge base of mechanistic pathways leading to oxidation in postmortem beef tissues, which ultimately leads to development of preventative measures for oxidative stress in beef cattle. The PI has been disseminating the knowledge through journal publication and more than twice a year talks at county cattlemen meetings, reaching approximately 100 stakeholders.

**Michigan – McKendree:** The long term goal of this research is to help producers understand how market forces impact their bottom line. While primary suppliers are often not directly involved in primary demand activities in vertically-connected industries, this study highlights the key economic value for primary suppliers to support demand enhancing activities.

The second long term goal is to increase the adoption of best management practices to ensure the long term sustainability of the US beef industry. Overall, BMP adoption has been low in the beef industry. By stepping back to understand what factors motivate producers current set of management practices, we can inform educational efforts on BMP adoption. Increased BMP adoption could influence consumer perceptions of beef producer, minimize animal health and disease risk, and strengthen the beef supply chain.

**Montana – Yeoman:**

Related Grants obtained:

New Grants

2019-05885-12901228

USDA – AFRI grant to Yeoman CJ. 2020 – 2025. Molecular Interrogation of Microbial Modulators of Bovine Immune Function.$500, 000

Previously Reported

Bair Ranch Foundation grant to Yeoman CJ (Co-PIs Carr C, Bothner B). 2019 - 2021. Identification and Cultivation of Methyllycaconitine-Degraders from Wild Ruminants to Protect Against Larkspur Poisoning of Range Cattle. $71,913

USDA – AFRI grant to Menalled F (Co-PIs Bourgault, M, Seipel T, Trowbridge A, Weaver D, Yeoman CJ. 2018 – 2022. Diversifying cropping systems through cover crops and targeted grazing: impacts on plant-microbe-insect interactions, yield and economic returns.$499,948.

**North Dakota – Maddock:** Beef produced in the U.S. is considered to be among the highest quality and safest in the world. By deepening our understanding of factors that affect beef quality, tenderness, and consumer preference we contribute to the quality of U.S. Beef.

**Nebraska – Calkins and Sullivan:** Research has been conducted investigating the effects cattle diet, biochemical processes (oxidative stress), ingredients, processing, and packaging on beef and beef products quality, shelf life, and safety. These can be used by beef producers and processors to ensure production of high quality beef.

Calkins received a grant from the Nebraska Beef Council to support research on oxidative stress ($49,424,8/2018-7/2020) and the research on dry aging was previously funded by the Nebraska Beef Council ($38,136, 8/2018 – 7/2020). A second project on accelerated dry aging was funded for $59,833 (10/1/2019 – 9/39/2020) by the Nebraska Beef Council.

**Nevada – De Mello:** Research developed in Nevada isdirectly aligned with the objectives of the W-4177 multi state project. De Mello developed methodologies that can be directly to the meat industry either to improve safety or quality of American beef. In addition, De Mello’s approach in elucidating the effects of beef-derived microRNAs aim to elucidate the global concern about meat mediating human health status. Besides two hatch grants, De Mello was awarded 3 extramural grants (NCBA – Systematic literature review on beef and meat consumption on psychological health, $28,996; USDA-NIFA- Mixing brewers spent grains and on-farm resources to improve production and profitability of small and medium-sized farms, $492,296, and a private research funding of $ 200,000). De Mello was also awarded the University of Nevada Cooperative Extension Outstanding Academic Faculty of the Year and Erica Shebs, his M.S. student, the Outstanding Graduate Student University of Nevada, Reno award

**Tennessee – Thompson, Myer, and Kojima:** Long term major goals of the project are:

1. Improve understanding of biosecurity policies to mitigate risk of adverse health or disease events within the U.S. beef industry. Determine how alternative indemnity policy situations and governmental cost share programs impact voluntary biosecurity efforts and hence competitiveness of U.S. beef.
2. Identify ongoing market risk associated with domestic livestock protocols to the U.S. beef industry. Improve quality, safety, and domestic and international marketability of U.S. beef products by examining palatability attributes, developing and applying novel food safety interventions, exploring metagenomics to investigate food safety and antimicrobial resistance, increasing shelf life, developing novel products from variety meat items, and developing innovate carcass fabrication techniques.

 Both of these goals provide better understanding of beef health and how those protocols affect production and marketability of U.S. beef.

**7. Publications**

**California – Oltjen**:

1. Andreini, E.M., S.M. Augenstein, C.S. Fales, R.D. Sainz and J.W. Oltjen. 2019. Effects of feeding level on efficiency of high and low residual feed intake beef steers. In: Energy and Protein Metabolism and Nutrition (M.L. Chizzotti, Ed.) pp. 133-134. European Assoc. for Anim. Prod. Publ. No. 138. Doi: 10.3920/978-90-8686-891-9\_10.
2. Dougherty, H.C., A. Ahmadi, J.W. Oltjen, F.M. Mitloehner and E. Kebreab. 2019. Modeling production and environmental impacts of small ruminants—Incorporation of existing ruminant modeling techniques, and future directions for esearch and extension. Applied Animal Science 35:114-129. <https://doi.org/10.15232/aas.2018-01753>
3. Dougherty, Holland C., James W. Oltjen, Frank M. Mitloehner, Edward J. DePeters and Lee Allen Pettey. 2019. Carbon and blue water footprints of California sheep production. Journal of Animal Science 97:945–961. <https://doi.org/10.1093/jas/sky442>
4. Fernandez, E.E., J.W. Oltjen and R.D. Sainz. 2019. Mitochondrial abundance and function inmuscle from beef steers with divergent residual feed intakes. In: Energy and Protein Metabolism and Nutrition (M.L. Chizzotti, Ed.) pp. 225-226. European Assoc. for Anim. Prod. Publ. No. 138. Doi: 10.3920/978-90-8686-891-9\_10.

**Colorado –Keith Belk and Mahesh Nair:**

1. Zhai, C., Peckham, K., Belk, K.E., Ramanathan, R., Nair, M.N\* (2019). Carbon chain length of lipid oxidation products influence lactate dehydrogenase and NADH-dependent metmyoglobin reductase activity. Journal of Agricultural and Food Chemistry. 67, 13327−13332.
2. Nair, M.N., Canto, A.C.V.C.S., Rentfrow, G., Suman, S.P. (2019). Muscle-specific effect of aging on tenderness of three beef hindquarter muscles. LWT Food Science and Technology, 100, 250–252.
3. Weinroth, M. D. et al. 2019. Investigation of tylosin in feed of feedlot cattle and effects on liver abscess prevalence, and fecal and soil microbiomes and resistomes. J. Anim. Sci. 97: 4567-4578.
4. Davis, H. E. et al. 2019. Quantification of ractopamine residues on and in beef digestive tract tissues. J. Anim. Sci. 97: 4193-4198.
5. Weinroth, M. D., N. R. Noyes, P. M. Morley, and K. E. Belk. 2019. Metagenomics of Meat and Poultry. Food Microbiology: Fundamentals And Frontiers: 939-962.
6. Gredell, D. A. et al. 2019. Comparison of machine learning algorithms for predictive modeling of beef attributes using rapid evaporative ionization mass spectrometry (REIMS) data. Sci. Rep. 9: 1-9.

**Idaho – Phil Bass and Michael Colle:**

*Peer-reviewed articles*

1. Hoffman, K.C., M.J. Colle, J.A. Nasados, S.J. Gray, J.Rogers, J.B. Van Buren, K.J. Puga, G.K. Murdoch, R.P. Richard, and M.E. Doumit. 2020. Relationship between heifer carcass maturity and beef quality characteristics. Transl. Anim. Sci. 4:1-10
2. Capouya, R.D., T. Mitchell, D.I. Clark, and P.D. Bass. 2020. A survey of microbial communities on dry-aged beef in commercial meat processing facilities. Meat and Muscle Bio. 4:1-11
3. Weber, T.M., M.J. Colle, G.K. Murdoch, B.J. Buseman, J.M. Lancaster, J.B. Van Buren, J.A. Nasados, and P.D. Bass. 2020. Using genetic panels to predict tenderness in beef cattle. Meat and Muscle Bio. (Accepted May 4, 2020)
4. Prill, L.L., L.N. Drey, E.A. Rice, B.A. Olson, J. M. Gonzalez, J.L. Vipham, M.D. Chao, P.D. Bass, M.J. Colle, and T.G. O’Quinn. 2019. Do published cooking temperatures correspond with consumer and chef perceptions of steak degrees of doneness. *Meat and Muscle Bio*. (3:510-525)
5. Prill, L.L, L.N, Drey, B.A. Olson, E.A. Rice, J.M. Gonzalez, J.L. Vipham, M.D. Chao, P.D. Bass, M.J. Colle, and T.G. O’Quinn. 2019. Visual degree of doneness impacts beef palatability for consumers with differing degree of doneness preferences. *Meat and Muscle Bio*. (3:411-423)

Review Papers

1. Nielsen, B., **M.J. Colle**, and G. Unlu. 2020. Review: Meat safety and quality: a biological approach. *International Journal of Food Science & Technology*. (Accepted April 30, 2020) 10.1111/ijfs.14602

*Abstracts*

1. Murillo, M.T., M.J. Beriain, J.A. Mendizabal, D. Garcia, M. Romano-Moreno, M.J. Colle, P.D. Bass, J.M. Lancaster, R. Barrena, and K. Insausti. 2020. Dry aging effects on the sensory quality of lean beef. European Conference on Sensory and Consumer Research. Rotterdam, The Netherlands, September 6, 2020.
2. Buseman, B., T. Weber, J. Nasados, P. Bass, J. Van Buren, J. Lancaster, J. Smart, M. Doumit, G. Murdoch, W. Price, K. Insausti, and M. Colle. 2020. Free calcium concentration, calpain-2 activity, and final product tenderness of electrically stimulated beef. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020 (Accepted)
3. Lancaster, J.M, B.J. Buseman, T.M. Weber, J.A. Nasados, G.K. Murdoch, W.J. Price, M.J. Colle, and P.D. Bass. 2020. Impact of beef carcass size on chilling rate, pH, display color and tenderness of top round subprimals. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020 (Accepted)
4. Weber, T.M, B.J. Buseman, J.A. Nasados, J.M. Lancaster, J.B. Van Buren, J.H. Smart, G.K. Murdoch, K. Insausti, P.D. Bass, and M.J. Colle. 2020. Assessing outcomes of genetic selection panels to predict marbling in crossbred beef cattle. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020 (Accepted)
5. Van Buren, J.B., B.J. Buseman, T.M. Weber, J.A. Nasados, J.M. Lancaster, J.H. Smart, P.D. Bass, and M.J. Colle. 2020. Extending the shelf-life of beef chuck roll using acerola cherry powder and rosemary extract. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020 (Accepted)

**Indiana – Kim:**

 Peer-review journal articles

1. Setyabrata, D., Kim, Y.H.B.\* 2019. Impacts of aging/freezing sequence on microstructure, protein degradation and physico-chemical properties of beef muscles. Meat Science. 151:64-74.
2. Teixeira, P.D., Tekippe, J.A., Rodrigues, L.M., Ladeira, M.M., Pukrop, J.R., Kim, Y.H.B., Schoonmaker, J.P.\* 2019. Effect of ruminally protected arginine and lysine supplementation on serum amino acids, performance and carcass traits of feedlot steers. 97:3511-3522.
3. Balan, P.\*, Farouk, M.M., Stuart, A.D., Kemp, R., Staincliffe, M., Craige, C., Kim, Y.H.B. 2019. Effects of electrical stimulation and pre-rigor conditioning temperature on ageing potential of hot-boned beef M. longissimus lumborum. Animal Science Journal. In Print.
4. Balan, P.\*, Kim, Y.H.B., Stuart, A.D., Kemp, R., Staincliffe, M., Craige, C., Farouk, M.M. 2019. Effect of fast freezing then thaw-aging on meat quality attributes of lamb M. longissimus lumborum. Animal Science Journal. In Print.

Abstracts

1. Setyabrata, D., Lee, J., Martini, S., Legako, J., Sobreira, T., Kim, Y.H.B.\* 2019. Further investigation of dry-aging impacts on palatability attributes and metabolomic profiles of beef loins. The 72nd Annual Reciprocal Meat Conference, Fort Collins, Colorado.
2. Ma, D., Suh, D.H., Zhang, J., Duttlinger, A., Johnson, J.S., Lee, C.H., Kim, Y.H.B.\* 2019. Apoptotic and proteolytic attributes and metabolomic changes in postmortem muscles from pigs subjected to post-weaning transport at different seasons. The 72nd Annual Reciprocal Meat Conference, Fort Collins, Colorado.
3. Xue, S., Setyabrata, D., Han, M., Xu, X., Kim, Y.H.B.\* 2019. Efficacy of beef crust from dry-aged beef loins as functional ingredient. The 72nd Annual Reciprocal Meat Conference, Fort Collins, Colorado.
4. Park, J.Y., Tuell, J.R., Wang, W., Cheng, H.W., Kim, Y.H.B.\* 2019. Functional/physicochemical properties and oxidative stability of ground meat from broilers exposed to different photoperiods. The 72nd Annual Reciprocal Meat Conference, Fort Collins, Colorado.

Conference Proceedings

1. Tuell, J.R.\*, Ma, D., and Kim, Y.H.B. 2019. Metabolomics Approach to Improve Meat Quality and Value. The 72nd Annual Reciprocal Meat Conference, Fort Collins, Colorado.
2. Setyabrata, D., Xue, S., Cramer, T., Vierck, K., Legako, J., Kim, Y.H.B.\* 2019. Dry-aging as value-adding process for beef loins from cull cow. In Proc. 65th International Congress of Meat Science and Technology. Berlin, Germany.
3. Zhang, J., Ma, D., Kim, Y.H.B.\* 2019. Mitochondrial apoptosis and proteolytic changes of myofibrillar proteins in two different pork muscles during aging. In Proc. 65th International Congress of Meat Science and Technology. Berlin, Germany.

**Kansas – Tonsor and Chao:**

Journal Articles:

1. Chun, C. K. Y., Wu, W.J., Welter, A. A., O’Quinn, T.G., Magnin-Bissel, G., Boyle,D. L., and Chao, M. D. (2020). A preliminary study to investigate the contribution of different tenderness factors to beef loin, tri-tip and heel tenderness. *Meat Science – In review*
2. Prill, L. L., Drey, L. N., Olson, B. A., Rice, E. A., Gonzalez, J. M., Vipham, J. L., Chao, M. D., Bass, P.D., Colle, M. J., and O’Quinn, T. G. (2019). Visual degree of doneness impacts beef palatability for consumers with different degree of doneness preferences. *Meat and Muscle Biology*, 3:411-423. doi:10.22175/mmb2019.07.0024
3. Olson, B. A., Rice, E. A., Prill, L. L., Drey, L. N., Gonzalez, J. M., Vipham, J. L., Chao, M. D., and O’Quinn, T. G. (2019). Evaluation of beef top sirloin steaks of four quality grades cooked to three degrees of doneness. *Meat and Muscle Biology*, 3:399-410. doi:10.22175/mmb2019.07.0022
4. Pozo, V.F., L.J. Bachmeier, and T.C. Schroeder. “Are there Price Asymmetries in the U.S. Beef Market?” Journal of Commodity Markets, in press.
5. Dennis, E.J., T.C. Schroeder, and D.G. Renter. “Net Return Distributions when Metaphylaxis is used to Control Bovine Respiratory Disease in High Health Risk Cattle.” Translational Animal Science in press.
6. Tonsor, G.T. and L.L. Schulz. “Will an Incentive-Compatible Indemnity Policy Please Stand Up? Livestock Producer Willingness to Self-Protect.” *Transboundary and Emerging Diseases.* In press.
7. Moon, D. and G.T. Tonsor. (2020). “How do *E.coli* Recalls Impact Cattle and Beef Prices?” *Journal of Agricultural and Resource Economics*. 45:92-106.

Abstracts:

1. Wu, W. J., Welter, A. A., O’Quinn, T.G., Magnin-Bissel G., and Chao, M. D. (2020). Utilizing mature collagen crosslinks as markers to predict cooked beef shin/shank meat texture, *Proceedings of 73rd Reciprocal Meats Conference*, Orlando, FL – in review
2. Chun, C. K. Y., Wu, W.J., Welter, A. A., O’Quinn, T.G., Magnin-Bissel, G., Boyle,D. L., and Chao, M. D. (2020). A preliminary study to investigate the contribution of different tenderness factors to beef loin, tri-tip and heel tenderness. *American Society of Animal Science Midwest Section*, Omaha, NE
3. Wu, W.J., Rice E. A., Olson B. A., O’Quinn, T.G., Houser, T.A., Boyle, E. A. and Chao, M.D. (2019) Sensory and Visual Evaluation of Six Different Beef Shank Cuts from Asian Consumers, *Proceedings of 72nd Reciprocal Meats Conference*, Fort Collins, CO

Other Publications:

1. Shear, H.E. , C. Kniebel, D.L. Pendell, and B. White. “Implementation & Economic Impacts of a Traceability Program on Beef Industry Stakeholders.” Kansas State University, Department of Agricultural Economics. December 2019.
2. Bowman, W. , Pendell, D.L., and K.L. Herbel. “Differences Between High-, Medium-, and Low-Profit Cow-Calf Producers: An Analysis of 2014-2018 Kansas Farm Management Association Cow-Calf Enterprise.” Kansas State University, Department of Agricultural Economics. September 2019.
3. Tonsor, G.T. “Overview of US Beef Production, Export, Import, and Domestic Consumption Trends: 2003-2019.” May 21, 2020.
4. Tonsor, G.T., LL. Schulz, and J.L Lusk. “Meat Availability and Shortages Overview.” April 28, 2020.
5. Tonsor, G.T. and Lee Schulz. “Fed Cattle Flows: Demonstrative Scenario Examples.” April 28, 2020.
6. Tonsor, G.T. and Lee Schulz. “Assessing Impact of Packing Plant Utilization on Livestock Prices.” April 4, 2020.
7. Tonsor, G.T. “Meat Demand Monitor - COVID19 Impact Special Report.” March 26, 2020.
8. Tonsor, G.T. “Cattle Industry’s COVID19 Economic Damage Assessment.” KSU-AgEcon-GTT-2020.1. March 2020.
9. Schroeder, T.C., L.L. Schulz, and G.T. Tonsor. “Feasibility Assessment of Reporting
10. Negotiated Slaughter Cattle Purchases in Separate Delivery Window Categories.” Report
11. Submitted to the USDA Agricultural Marketing Service. November 2019.
12. Tonsor, G.T. “Overview of MCOOL Impact on KSU Domestic Beef and Pork Demand Indices.” KSU-AgEcon-GT-2019.3. September 2019.

**Kentucky – Suman:**

1. Salim, A.P.A.A.; Suman, S.P.; Canto, A.C.; Costa-Lima, B.R.; Viana, F.M.; Monteiro, M.L.; Silva, T.J.P.; Conte-Junior, C.A. 2019. Muscle-specific color stability in fresh beef from grain-finished Bos indicus cattle. Asian-Australasian Journal of Animal Sciences, 32: 1036-1043.
2. Kim, H.M.; Suman, S.P.; Li, S.; Beach, C.M.; Nair, M.N.; Zhai, C.; Edenburn, B.M.; Felix, T.L.; Dilger, A.C.; Boler, D.D. 2019. Ractopamine-induced changes in the proteome of post-mortem beef longissimus lumborum muscle. South African Journal of Animal Science, 49: 424-431.
3. Salim, A.P.A.A.; Suman, S.P.; Canto, A.C.; Costa-Lima, B.R.; Viana, F.M.; Monteiro, M.L.; Silva, T.J.P.; Conte-Junior, C.A. 2019. Influence of muscle source on protein oxidation, texture profile and proximate composition of beef from grain-finished Bos indicus cattle. Ciencia Rural, 49: e20180996
4. Salim, A.P.; Suman, S.P.; Viana, F.M.; Monteiro, M.L.; Panzenhagen, P.H.N.; Canto, A.C.; Conte-Junior, C.A. 2019. Harvest method influences color stability of longissimus lumborum steaks from Bos indicus cattle. Meat and Muscle Biology, 3: 33-41.
5. Zhai, C.; Suman, S.P.; Nair, M.N.; Li, S.; Luo, X.; Beach, C.M.; Harsh, B.N.; Boler, D.D.; Dilger, A.C.; Shike, D.W. 2018. Supranutritional supplementation of vitamin E influences mitochondrial proteome profile of post-mortem longissimus lumborum from feedlot heifers. South African Journal of Animal Science, 48: 1140-1147.
6. Suman, S.P.; Rentfrow, G.; Wang, Y.; Nair, M.N. 2019. Muscle-specific color stability in fresh meats from ruminants. Meatingplace Online. <http://www.meatingplace.com/Industry/TechnicalArticles/Details/87676>
7. Nair, M.N.; Rentfrow, G.; Canto, A.C.V.C.S.; Wang, Y.; Li, S.; Joseph, P.; Ramanathan, R.; Hoffman, L.C.; Sun, Q.; Salim, A.P.A.; Conte-Junior, C.A.; Mancini, R.; Suman, S.P. A global perspective on muscle-specific color stability in fresh meats. In proceedings of American Meat Science Association Annual Reciprocal Meat Conference, June 2019, Fort Collins, CO.
8. Zhai, C.; Suman, S.P.; Li, S.; Nair, M.N.; Beach, C.M.; Edenburn, B.M.; Boler, D.D.; Dilger, A.C.; Felix, T.L. 2019. Ractopamine-induced changes in the mitochondrial proteome of postmortem beef longissimus lumborum. American Meat Science Association Annual Reciprocal Meat Conference, June 2019, Fort Collins, CO, Abstract # 139.
9. Kim, H.M.; Suman, S.P.; Li, S.; Beach, C.M.; Zhai, C.; Nair, M.N.; Harsh, B.N.; Boler, D.D.; Dilger, A.C.; Shike, D.W. 2019. Supranutritional supplementation of vitamin E influences the abundance of antioxidant proteins in postmortem longissimus lumborum from heifers. American Meat Science Association Annual Reciprocal Meat Conference, June 2019, Fort Collins, CO, Abstract # 142.

**Michigan – McKendree:**

1. McKendree, M.G.S**.**, G.T. Tonsor, T.C. Schroeder, and N.P. Hendricks. (2019) “Impacts of

retail and export demand on United States cattle producers.” *American Journal of Agricultural Economics*, <https://doi.org/10.1093/ajae/aaz034>

Popular Press

1. McKendree, M.G.S. “Understanding U.S. Beef Demand.” Michigan Farm News. September 15, 2019.
2. Also printed in The Michigan Cattleman. Winter 2019. Volume 24, Issue 4.

Journal Articles

1. McKendree, M.G.S**.**, G.T. Tonsor, T.C. Schroeder, and N.P. Hendricks. (2019) “Impacts of

retail and export demand on United States cattle producers.” *American Journal of Agricultural Economics*, <https://doi.org/10.1093/ajae/aaz034>

**Mississippi – Dinh:**

1. Sukumaran, A. T., Coatney, K, Ellington, J., Holtcamp, A. J., Schilling, M. W., & Dinh, T. T. (2019). Consumer acceptability and demand for cooked beef sausage formulated with pre- and post-rigor deboned beef. *Meat & Muscle biology*, *3(1)*, 210-218.
2. Holtcamp, A.J., Sukumaran, A.T., Schnedler, A.E., McClenton, B.J., Kunze, E., Calkins, C.R., Karisch, B.B., Burnett, D.D., Dinh, T.T. (2019). Effects of feeding endophyte-infected tall fescue seeds to stocker Angus steers on retail quality attributes of beef strip steaks. *Meat Science*, *149*, 31-39.
3. McClenton, B. J, Goodman, J., Dong, O., Sukumaran, A., Holtcamp, A., Hart, C., Lemley, C. O., Aiken, G., Schilling, W., Baldwin, B., Martin, S., Blanton, J., & Dinh, T. 2019. Effects of feeding endophyte-infected tall fescue seed to Angus steers on ergovaline concentration, lipid oxidation, and skeletal metmyoglobin reductase activity. 2019 Joint ASAS/CSAS Annual Meeting, Austin, TX.
4. Sajeev, D., Thames, H. T., Cobb, H. C., Sukumaran, A. T., Holtcamp, A, J., Cavender, A., de Mello, A., & Dinh, T. T. N. 2019. Effects of electrostatic spray and natural antioxidants on sensory quality and color of grass-finished beef strip steaks. 2019 Joint ASAS/CSAS Annual Meeting, Austin, TX.
5. Haines, C., Sajeev, D., Coatney, K., &Dinh, T. 2019. Impacts of chilling duration on marbling score, shrinkage, and lean color in beef carcasses. The 72nd Reciprocal Meat Conference of the American Meat Science Association. Loveland, CO.
6. Thames, H. T., Sajeev, D., Cobb, H. C., Sukumaran, A. T., Holtcamp, A. J., & Dinh, T. N. T. 2019. Effects of electrostatic spray and natural antioxidants on chemical quality of grass-finished beef strips steaks. The 72nd Reciprocal Meat Conference of the American Meat Science Association. Loveland, CO.

**Montana - Yeoman:**

1. Sanglard LP, Schmitz-Esser S, Gray KA, Linhares DCL, Yeoman CJ, Dekkers JCM, Niederwerder MC, Serão NVL. 2020. Vaginal microbiota diverges in sows with low and high reproductive performance after porcine reproductive and respiratory syndrome vaccination. Scientific Reports. 10: 3046 DOI: 10.1038/s41598-020-59955-8
2. Ishaq SL, Seipel T, Yeoman CJ, Menalled FD. 2020. Soil bacterial communities of wheat vary across the growing season and among dryland farming systems. Geoderma. 358: 113989
3. Sanglard LP, Schmitz-Esser S, Gray KA, Linhares DCL, Yeoman CJ, Dekkers JCM, Niederwerder MC, Serão NVL. 2019. Investigating the relationship between vaginal microbiota and host-genetics and their impact on immune response and farrowing traits in commercial gilts. Journal of Animal Breeding and Genetics. In press. DOI: 10.1111/jbg.12456
4. Ishaq SL, Lachman MM, Wenner BA, Baeza A, Butler M, Gates E, Olivo S, Geddes JB, Hatfield P, Yeoman CJ. 2019. Pelleted-hay alfalfa feed increases sheep wether weight gain and rumen bacterial richness over loose-hay alfalfa feed. PLoS One 14: e0215797. DOI: 10.1371/journal.pone.0215797
5. Knuth RM, Stewart WC, Taylor JB, Yeoman CJ, Bisha B, Page CM, Rowley CM, Lindsey BC, van Emon ML, Murphy TW. 2019. Subclinical mastitis in sheep: etiology and association with milk somatic cell count and ewe productivity in three research flocks in the Western U.S. Translational Animal Science 3: 1739 – 1743. DOI: 10.1093/tas/txz078
6. Ishaq SL, Page CM, Yeoman CJ, Murphy TW, Van Emon ML, Stewart WC. 2019. Zinc-amino-acid supplementation alters yearling ram rumen bacterial communities but zinc sulfate supplementation does not. Journal of Animal Sciences. 97: 687 – 697. DOI: 10.1093/jas/sky456.

**North Dakota – Maddock:**

1. Fevold, M. A, K. L. Grube, W. L. Keller, K. R. Maddock-Carlin, and R. J. Maddock. 2020. Tenderness and juiciness of beef steaks from varying hot carcass weights. Meat and Muscle Biology (Submitted)
2. Nath, S. D., M. A Fevold, R. J. Maddock, W. L. Keller, and K. R. Maddock-Carlin. 2020. The influence of carcass size on troponin-T degradation and heat shock protein 70 in two different muscles. Proc Recip. Meats Conf. (Abstract, Submitted)
3. Şentürklü, S., R. J. Maddock, D.G. Landblom, M.A. Fevold, and S. Paisley. 2020. Impact of grazing systems on carcass and meat quality attributes of yearling beef steers. Applied Animal Science. (Submitted)

**Nebraska – Calkins and Sullivan:**

Journal Articles

1. Giotto, F., Fruet, A. P. B., Nornberg, J. L., Calkins, C. R., and de Mello, A. (2020). Effects of muscle and finishing diets containing distillers grains with low moisture levels on fatty acid deposition in two novel value-added beef cuts. Food Science of Animal Resources. 40(3):484-494.
2. Bernardo, A. P., Silva, A., Francisco, V., Ribeiro, F. A., Nassu, R., Calkins, C., Nacimento, M., Pflanzer, S. (2020). Effects of freezing and thawing on microbiological and physical-chemical properties of dry-aged beef. Meat Science, 161.
3. Hall, H. R., Domenech, K. I., Wilkerson, E. K., Ribeiro, F. A., Jenkins, K., MacDonald, J., Calkins, C. (2020). Fresh beef quality from cattle fed field peas during pasture and finishing phases of production. Meat and Muscle Biology. 4(1): 11, 1-8.
4. Lau, S.K., Ribeiro, F.A., Subbiah, J., and Calkins, C.R. 2019. Agenator: An open source computer-controlled dry aging system for beef. Hardware X 6, e00086.
5. Henriott, M.L, Herrera, N.J., Ribeiro, F.A., Hart, K.B., Bland, N.A. and Calkins, C.R. 2020. Impact of myoglobin oxygenation level on color stability of frozen beef steaks. J. Anim. Sci. In Press.

Other Peer Reviewed Educational Material

1. Ribeiro, F. A., Lau, S. K., Henriott, M. L., Herrera, N. J., Bland, N. A., Subbiah, J., Calkins, C. (2020). Effects of Relative Humidity on Meat Quality in Dry Aged Beef. (vol. MP 108, pp. 107-109). The Nebraska Beef Cattle Report.
2. Norman, M. M., Bland, N. A., Boyd, B. A., Conroy, B. B., Watson, A. K., Erickson, G., Calkins, C. (2020). Evaluation of Green Grass as a Feed Ingredient in Beef Finishing Rations and Impact on Cattle Performance, Carcass Characteristics, and Fatty Acid Profiles in Beef. (vol. MP 108, pp. 78-82). The Nebraska Beef Cattle Report.
3. Bland, N. A., Ribeiro, F. A., Herrera, N. J., Henriott, M. L., Hart, K. B., Calkins, C. (2020). Impact of Diet and Quality Grade on Shelf Life of Beef Steaks. (vol. MP 108, pp. 114-119). The Nebraska Beef Cattle Report.
4. Henriott, M. L., Hart, K. B., Herrera, N. J., Ribeiro, F. A., Bland, N. A., Gwartney, B. L., Calkins, C. (2020). Impact of Feeding NaturSafe® (An Immune Support Product) on Beef Quality. (vol. MP 108, pp. 110-113). The Nebraska Beef Cattle Report.
5. Henriott, M. L., Ribeiro, F. A., Herrera, N. J., Hart, K. B., Bland, N. A., Calkins, C. (2020). Impact of Myoglobin Oxygenation State on Color Stability of Frozen Beef Steaks. (vol. MP 108, pp. 105-106). The Nebraska Beef Cattle Report.
6. Lau, S. K., Ribeiro, F. A., Subbiah, J., Calkins, C. (2019). Performance of an open source automatic dry aging system. American Society of Agricultural and Biological Engineers. Annual International Meeting. No. 1901539.
7. Henriott, M. L., Ribeiro, F. A., Hart, K. B., Herrera, N. J., Bland, N. A., Calkins, C. (2019). Impact of myoglobin oxygenation state at freezing on color stability of frozen and thawed beef. (vol. 97 (Supp. 2), pp. 44). Journal of Animal Science.

Abstracts

1. Bland, N. A., Riberio, F. A., Herrera, N., Hart, K., Henriott, M., Calkins, C. (2019). Impact of diet on shelf life of beef steaks. Journal of Animal Science. (Supplement 2 ed., vol. 97, pp. 55).
2. Henriott, M. L., Ribeiro, F. A., Hart, K. B., Herrera, N. J., Bland, N. A., Calkins, C. (2019) Color stability of fresh and frozen beef. (vol. 97 (Supp. 2)). Journal of Animal Science. 97(Supplement 2, vol. 97, pp. ).
3. Henriott, M. L., Ribeiro, F. A., Hart, K. B., Herrera, N. J., Bland, N. A., Calkins, R. (2019) Impact of myoglobin oxygenation state at freezing on color stability of frozen and thawed beef. Journal of Animal Science. 97(Supplement 2, vol. 97, pp. 44).
4. Calkins, C., Ribeiro, F. A., Lau, S. K., Herrera, N., Henriott, M., Bland, N., Pflanzer, S. B., Subbiah, J. (2019). Color and Lipid Stability of Dry Aged Beef During Retail Display. (pp. Abstract 54). Reciprocal Meat Conference Abstracts. American Meat Science Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
5. Henriott, M., Hart, K., Herrera, N., Ribeiro, F., Bland, N., Gwartney, B., Calkins, C. (2019). The Impacts of Feeding NatureSafe (an Immune Support product) on Beef Quality. (pp. Abstract 57). Reciprocal Meat Conference Abstracts. American Meat Science Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
6. Ribeiro, F. A., Lau, S. K., Herrera, N., Henriott, M., Bland, N., Subbiah, J., Calkins, C. (2019). Dry Aging of High Ultimate pH Beef. (pp. Abstract 49). Reciprocal Meat Conference Abstracts. American Meat Science Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
7. Bernardo, P. S., Caroline, A., Ribeiro, F. A., Calkins, C., do Nascimento, M.D.S., Pflanzer, S. B. (2019). Dry-Aging: How Freezing Can Affect the Yield and Quality of Beef? (pp. Abstract 53). Reciprocal Meat Conference Abstracts. American Meat Science Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
8. Henriott, M., Ribeiro, F., Herrera, N., Hart, K., Bland, N., Calkins, C. (2019). Impact of Myoglobin Oxygenation State at Freezing on Color Stability of Frozen Beef. (pp. Abstract 48). Reciprocal Meat Conference Abstracts. American Meat Science Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
9. Torres-Burgos, I., Sánchez-Rodríguez, H., Pagán-Morales, M., Casas-Guernica, A., Calkins, C., Domenech-Pérez, K. (2019). pH Variability and Its Relationship with Sarcomere Length and Free Calcium in Beef from Commercial Cattle in Puerto Rico. (pp. Abstract 138). Reciprocal Meat Conference Abstracts. American Meat Science Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
10. Ribeiro, F. A., Lau, S. K., Herrera, N., Henriott, M., Bland, N., Pflanzer, S. B., Subbiah, J., Calkins, C. (2019). Relationship Between Relative Humidity and Moisture Loss in Dry Aged Beef. (pp. Abstract 55). Reciprocal Meat Conference Abstracts. American Meat sicence Association. https://meatscience.org/docs/default-source/default-document-library/abstract-by-number.pdf?sfvrsn=ac1b15cc\_0
11. Bland, N., Herrera, N., Henriott, M., Ribeiro, F., Hart, K., Calkins, C. (2020) Impact of Diet and Quality Grade on Tenderness of Beef Steaks. Journal of Animal Science. (Supplement 2 ed.,): In Press.
12. Norman, M., Bland, N., Boyd, B., Conroy, B., Calkins, C., Watson, A., Erickson, G. (2020) Evaluation of Green Grass as a Feed Ingredient in Beef Finishing Rations and Impact on Cattle Performance, Carcass Characteristics, and Fatty Acid Profiles in Meat. Journal of Animal Science. (Supplement 2 ed.,): In Press.
13. Bower, C. G., Samodha, F., Sullivan. G.A.. 2019. Spoilage Microbiota Of Beef Throughout Various Phases Of Processing. Reciprocal Meat Conference Abstracts. American Meat Science Association.

Thesis

Herrera, N.J. 2020. The Impact of Oxidative Stress on Postmortem Meat Quality. Master's Thesis, University of Nebraska-Lincoln, Lincoln, NE.

Bland, N.A. 2020. Impact of Diet and Quality Grade on Meat Quality Characteristics and Their Relationship to Oxidative Stress. Master's Thesis, University of Nebraska-Lincoln, Lincoln, NE.

Bower, C.G. 2019. Factors influencing spoilage and microbial population on the shelf life of processed meats. Ph.D. Dissertation. University of Nebraska-Lincoln, Lincoln, NE.

Presentations

1. Calkins, C., 2nd University of Nebraska and State University of Campinas (Brazil) Symposium "Creating and Marketing High Quality Beef", University of Nebraska, State University of Campinas and São Paulo Research Foundation (FAPESP), Campinas, Brazil, "Adding Value to Beef." (December 13, 2019).
2. Calkins, C., Beef Quality Meeting, Prime Cater Co., Sao Paulo, Brazil, "Building a Satisfied Customer",
3. Calkins, C., UNL Beef Summit, UNL Animal Science Beef Scholars, Lincoln, NE, "Cutting Demonstration - Cutting Beef to Add Value."
4. Calkins, C., UNL Beef Summit, UNL Animal Science Beef Scholars, Lincoln, NE, "The Nebraska Advantage – Producing Quality Beef and Value-Adding Strategies."
5. Calkins, C., Nebraska Youth Beef Leadership Symposium, UNL Animal Science, Lincoln, NE, "Elements of Beef Palatability"
6. Calkins, C., Dawson County Cattlemen meeting, Gothenburg, NE, "Promoting the Quality of Beef from Nebraska Around the World."
7. Calkins, C., The University of Nebraska Meat Science Program, UNL - IANR Office of Global Engagement, Lincoln, NE, "Cutting demonstration - Value-Adding Strategies for Beef"
8. Calkins, C., The University of Nebraska Meat Science Program, UNL-IANR Office of Global Engagement, Lincoln, NE, "Muscle Profiling – Adding Value through New Meat Cuts."
9. Calkins, C., The University of Nebraska Meat Science Program, UNL - IANR Office of Global Engagement, Lincoln, NE, "Production of Quality Beef – The Nebraska Advantage."
10. Calkins, C., Excellence from Farm to Table, Nebraska Department of Agriculture and Albers Meat Co., Cologne, Germany, "Quality Beef from Nebraska"
11. Calkins, C., Nebraska MEATing, Nebraska Department of Agriculture and Inalca Food Co., Cologne, Germany, "Quality Beef from Nebraska"
12. Calkins, C., ASCI 95 - Freshman Orientation, UNL Animal Science, Lincoln, NE, "Career Opportunities in Meat Science"
13. Calkins, C., Meat Quality Discussion, Meta Foods Co., Lincoln, NE, "Demonstration of Cutting the Value Cuts - Opportunities for Profit"
14. Calkins, C., Meat Quality Discussion, Meta Foods Co., Lincoln, NE, "Muscle Profiling - Adding Value to Beef"
15. Calkins, C., Meat Quality Discussion, Meta Foods Co., Lincoln, NE, "The Nebraska Advantage - Quality Beef from Nebraska"
16. Calkins, C., Meat Quality Session, A.R.G. Grupo, Bela Horizonte, Brazil, "The Science Behind Quality Beef"
17. Calkins, C., 7th Brazilian Ruminant Nutrition Symposium, University of Sao Paulo - Botucatu, Botucatu, Brazil, "The Impacts of Nutrition on Meat Quality."
18. Calkins, C., Argentine Beef Producer group, Lincoln, NE, "Production of Quality Beef in Nebraska"
19. Calkins, C., Quality of Beef from Nebraska, Nebraska Department of Agriculture, Lincoln, NE, "Cutting Demonstration for the Value Cuts - Opportunities for Added Profit"
20. Calkins, C., Quality of Beef from Nebraska, Nebraska Department of Agriculture, Lincoln, NE, "Muscle Profiling - Value Adding Opportunities"
21. Calkins, C., Quality of Beef from Nebraska, Nebraska Department of Agriculture, Lincoln, NE, "The Nebraska Advantage - Producing Quality Beef in Nebraska."
22. Calkins, C., The University of Nebraska Meat Science Program, UNL - IANR Office of Global Engagement, Lincoln, NE, "Beef Value Cuts - New Value Opportunities"
23. Calkins, C., International Congress of Meat Science and Technology, Potsdam/Berlin, Germany, "Research Poster Discussion Leader"
24. Calkins, C., Nebraska Ag. Youth Institute, Nebraska Department of Agriculture and UNL-IANR, Lincoln, NE, "The Nebraska Advantage - Producing Quality Beef"
25. Calkins, C., Ribeiro, F. A., Reciprocal Meat Conference, American Meat Science Association, Fort Collins, Colorado, "The Art and Science of Dry-Aged Beef"
26. Calkins, C., Mandigo, R., Meat Processing Workshop, UNL and the U.S. Meat Export Federation, Lincoln, NE, "Meat Packaging Options"
27. Calkins, C., Meat Processing Workshop, UNL and the U.S. Meat Export Federation, Lincoln, NE, "Basic meat science – important meat quality concepts."
28. Calkins, C. Invited Seminarian, Iowa State University “Bring Science to the Art of Dry-Aged Beef.”
29. Calkins, C. Nippon Steel Customer Education Workshop in Tokyo, Japan “Quality Beef from Nebraska.”
30. Calkins, C. Nippon Steel Beef Merchandising Team in Tokyo, Japan “The Science of Quality Beef from Nebraska.”
31. Calkins, C. Japanese Meat Importers Seminar – co-hosted by U.S. Meat Export Federation in Tokyo, Japan “The Reasons Beef from Nebraska is such High Quality.”
32. Calkins, C. Japanese Meat Importers Seminar – co-hosted by U.S. Meat Export Federation in Tokyo, Japan “Value cuts from the beef chuck roll – a meat cutting demonstration.”
33. Sullivan, G. Nebraska Youth Beef Leadership Symposium. University of Nebraska in Lincoln, NE. “Beef and It’s Opportunities.”
34. Sullivan, G. Nebraska Youth Beef Leadership Symposium. University of Nebraska in Lincoln, NE. “Beef and It’s Opportunities.”
35. Sullivan, G. Maruha Nichiro Corp. visit to UNL. University of Nebraska “Meat Processing at UNL.”
36. Sullivan, G. UNL Food Processing Center HPP workshop. University of Nebraska. “HPP Applications in the Meat, Seafood Dairy, Fruits, Vegetables and Beverage Industries.”
37. Sullivan, G. Meat Processing Workshop. U.S. Meat Export Federation. Lincoln, NE. “Basics of meat processing.”
38. Sullivan, G. Meat Processing Workshop. U.S. Meat Export Federation. Lincoln, NE. “Thermal processing.”
39. Sullivan. G. NAMP Annual Convention, Nebraska Association of Meat Processors. Grand Island, NE. “Thermal Processing – Jerky.”
40. Sullivan, G. Faces of Leadership Conference. National Junior Hereford Association, Lincoln, NE. “What is the difference between a hamburger and a hot dog?”

**Nevada – De Mello:**

Journal Articles

1. Fruet, A.P.B., Giotto, F.M., Fonseca, M.F., Nörnberg, J.L., and de Mello, A.S. 2020, Effects of the incorporation of tannin extract from Quebracho Colorado wood on color Parameters, lipid oxidation, and sensory attributes of beef patties, Foods 2020, 9(5), 667.

2. Giotto, F. M. Fruet, A. P. B., Nörnberg J. L.,Calkins, C. R., de Mello, A. S. 2020, Effects of muscle and finishing diets containing distillers grains with low moisture levels on fatty acid deposition in two novel value-added beef cuts, Food Science of Animal Resources, pISSN: 2636-0772, eISSN: 2636-0780.

3. Shebs. E.L., Lukov, M.J., Giotto, F.M., Torres, E.S., de Mello, A.S. 2020, Efficacy of bacteriophage and organic acids in decreasing STEC O157:H7 populations in beef kept under vacuum and aerobic conditions: A simulated High Event Period scenario, Meat Science. Volume 162, April 2020.

Abstracts

1. Shebs, E. L., Giotto, F. M., Laidler, S. T., & de Mello, A. S. 2020. Effects of bacteriophages and peroxyacetic acid applications on beef contaminated with *Salmonella* during different grinding stages. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020.

2. Cavender, A. M., Giotto, F. M., Miller, D., Dinh, T., de Mello A.S. 2020. Effects of dry and wet aging on volatile and amino acid profile of USDA Choice and Prime strip loins. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020.

3. Giotto, F. M., Cavedner, A. M., Shebs, E. L., Fonseca, M. F., de Mello, A. S. 2020. 66th International Congress of Meat Science and Technology and 73rd Reciprocal Meat Conference. Orlando, FL, August 2, 2020.

Conference Proceedings

1.Giotto, F. M., Evans, L. W., Ferguson, B. S., de Mello A. S. 2019. Availability of human homologous dietary microRNAs in cooked beef. 65th International Congress of Meat Science and Technology, Berlin, Germany.

2. Cavender, A. M., Giotto, F. M., de Mello, A. S. 2019. Effects of dry and wet aging on sensory attributes, instrumental tenderness, and lipid peroxidation of USDA-Choice and USDA-Prime tenderloins. 65th International Congress of Meat Science and Technology, Berlin, Germany.

Thesis

1. Bacteriophage solutions as processing aids in beef production: An essential hurdle to reduce E. coli O157:H7 and the “Big Six” serotypes. 2019. M.S. Erica L. Shebs

Technical reports

1. De Mello, A. S. 2019. Understanding the USDA Beef Grading System Progressive Rancher, U.S., <http://progressiverancher.com/issue-nov-dec-2019/>

**Tennessee –Thompson, Myer, Kojima:**

1.Muhammad, A., J. Thompson, and K. Delong. “Reversing KORUS: Assessing the Benefits of the Korea-US Trade Agreement on Agriculture.” Agribusiness. 13(4). 2020.

2.Thompson, J., C. Trejo-Pech, and D. Pendell. “Agribusiness Profitability Impacts of Highly Pathogenic Avian Influenza Outbreak.” Agricultural Finance Review. 79(3). 2019.

3.Thompson, J., D. Pendell, T. Boyer, K. Patyk, S. Malladi, and J.T. Weaver. “Economic Impact of HPAI Outbreak on Minnesota Egg Laying Operations.” Journal of Agricultural and Applied Economics. 51(2). 2019.

4.Kuczewski, A., H. Hogeveen, K. Orsel, R. Wolf, J. Thompson, E. Spackman, and F. van der Meer. “Economics of on-farm Bovine Leukemia Virus Control.” Journal of Dairy Science. 102(3). 2019.

5.Clemmons, B.A., Martino, C., Schneider, L.G., Lefler, J., Embree, M.M., and Myer, P.R. 2019. Temporal stability of the ruminal bacterial communities in beef steers. Scientific Reports. 9:9522. doi: 10.1038/s41598-019-45995-2

6.Myer, P.R., Clemmons B.A., Schneider, L.G., and Ault, T.B. 2019. Microbiomes in Ruminant Protein Production and Food Security. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. 14(8):1-11. doi: 10.1079/PAVSNNR201914008.

7.Clemmons, B.A., Powers, J.B., Campagna, S.R., Seay, T.B., Embree, M.M., Myer, P.R. 2019. Rumen Fluid Metabolomics of Beef Steers Differing in Feed Efficiency. Metabolomics.

8.Clemmons, B.A., Campbell, M.A., Schneider, L.G., Grant, R.J., Dann, H.M., Krawczel, P.D., Myer, P.R. 2019. Rumen Bacteria and Serum Metabolites Predictive of Feed Efficiency Phenotypes in Beef Cattle. Scientific Reports.

9.Clemmons, B.A., Martino, C., Powers, J.B., Campagna, S.R., Voy, B.H., Donohoe, D.R., Gaffney, J., Embree, M.M., Myer, P.R., 2019. Rumen Bacteria and Serum Metabolites Predictive of Feed Efficiency Phenotypes in Beef Cattle. bioRxiv, p.701300.

Confernece Papers and Presentations

1.Thompson, J., A. Delgado\*, H. Hasel, and D. Bonilla. “Effects of Drought and Media-Reported Violence on Cattle Fever Tick Incursions.” 123rd Annual Meeting of the United States Animal Health Association, Providence, Rhode Island, October 24-30, 2019.

2.Trejo-Pech, C. and J. Thompson\*. “A Stochastic Financial Analysis of Cage and Cage-free Egg Production in the United States.” Agricultural and Applied Economics Association Annual Meeting, Atlanta, Georgia, July 21-23, 2019.

3.Boyer, C., J. Thompson, A. Griffith, K. Laurent, and X. Cui. “Bred Heifer Price Determinants.” Poster Presentation. Agricultural and Applied Economics Association Annual Meeting, Atlanta, Georgia, July 21-23, 2019.

4.Campbell, V., J. Thompson\*, D.L. Pendell, G. Tonsor, and W. Preston. “Producer’s Willingness-to-Invest in On-Farm Carcass Disposal: A Study on U.S. Poultry.” Western Economics Association International Annual Meeting, San Francisco, California, June 28-30, 2019.

5.Campbell, V. \* and J. Thompson. “Farmer Perception of Current U.S. Livestock Indemnity Policy.” Southern Agricultural Economics Association Annual Meeting, Birmingham, Alabama, February 2-5, 2019.

6.Berman, S. \*, J. Thompson, H. Hasel, D. Bonilla, and A. Delgado. “Effects of Drought and Media-Reported Violence on Cattle Fever Tick Incursions.” Southern Agricultural Economics Association Annual Meeting, Birmingham, Alabama, February 2-5, 2019.

7.Myer, P.R. 2019. Understanding the impact of the rumen microbiome on beef cattle performance. Microbiome Movement Animal Health & Nutrition Conference. St. Louis, MO.

8.Clemmons, B.A., Henniger, M.T., Powers, J.B., Mulliniks, J.T., Campagna, S.R., Embree, M.M., Voy, B.H., and Myer, P.R. 2019. Rumen fluid metabolites associated with feed efficiency in Angus steers. ASAS-CSAS Annual Meeting and Trade Show, Austin, TX.

9.Clemmons, B.A., Henniger, M.T.\*, Voy, B.H., Donohoe, D.R., and Myer, P.R., 2019. Effects of rumen content exchange on bacterial community dynamics and production-relevant parameters. Poster Presentation. ASM Microbe Annual Meeting. San Francisco, CA.

10.Clemmons, B.A., Campbell, M.A., Grant, R.J., Dann, H.M., Krawczel, P.D., Schneider, L.G., and Myer, P.R. 2019. Effect of stocking density on ruminal bacterial communities of Holstein dairy cows. Poster Presentation. ASM Microbe Annual Meeting. San Francisco, CA.

11.Clemmons, B.A., Martino, C., Schneider, L.G., Embree, M.M., Myer, P.R. 2019. Temporal stability of the ruminal bacterial communities in beef steers. Oral Competition. Congress on Gastrointestinal Function. Chicago, IL.

12.Henniger, M.T., Myer, P.R., Smith, T.P.L., McDaneld, T., Kuehn, L.A., and Keele, J. 2019. A 16S rDNA reference database of the deep-nasopharynx in steers for bacterial community analysis of cattle with bovine respiratory disease complex. Poster Competition. ASAS Midwest Annual Meeting. Omaha, NE. Journal of Animal Science, 97(Supplement 2)251. doi: 10.1093/jas/skz122.442

13.Clemmons, B.A., Henniger, M.T.\*, Powers, J.B., Campagna, S.R., Voy, B.H., Donohoe, D.R., Myer, P.R. 2018. Rumen and serum metabolomes differ in Angus cows. UTIA Graduate Student Research Poster Competition, Knoxville, TN. doi: 10.6084/m9.figshare.7429892

14.Henniger, M.T., Hales, K.E., Wells, J.E., Freetly, H.C., Clemmons, B.A., Myer, P.R. 2018. The effects of a moderate and aggressive implant strategy on the ruminal microbial community and metabolome in steers. UTIA Graduate Student Research Poster Competition, Knoxville, TN. doi: 10.6084/m9.figshare.7429892

Other

1.Myer, P.R. 2019. Ruminant Gut Microbe of the Month. rumenmicrobes.utk.edu

2.Myer, P.R. 2019. Maximizing Microbes: Improving feed efficiency and nutrition for sustainable beef. Retaking the Field Volume 4. Supporters of Agricultural Research Foundation (SoAR). [https://supportagresearch.org/our-projects/retaking- the-field/retaking-the-field-volume-4](https://supportagresearch.org/our-projects/retaking-%20the-field/retaking-the-field-volume-4)