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

Annual Report 2021

The W4177 Multistate Collaborators have had a successful year despite the challenging circumstances of the past year. This report will highlight collaborations of the members as well as station accomplishments, short-term outcomes, outputs, activities, milestones, impact statements, and publications.

1. **Collaborations**

**California (Oltjen) and Nevada (Fonseca):** Future collaboration for water and resource use in beef production

**Idaho (Bass) and Nebraska (Calkins):** Hosted a dry aging extension workshop for industry personnel and students.

**Idaho (Bass and Colle) and Mississippi (Dinh):** Conducted a project looking at the effect of electrical stimulation on flavor development. This resulted in an abstract at the reciprocal meat conference:

1. Wang, S, K.V. To, C. Dahlgren, C. Fornes, H. Hessler, X. Zhang, Y. Campbell, B. Buseman, P. Bass, M. Colle, M. Schilling, and T. Dinh. 2021. Free amino acid content in longissimus lumborum and semimembranosus muscles from electrically stimulated beef carcasses. Reciprocal Meat Conference, Reno, NV.
2. Wang, S., To, K. V., Dahlgren, C., Sajeev, D., Rivera, D., Schilling, M. W., Suman, S., Dinh, T. (2021). Lean color and oxidative stress biomarkers in post-rigor longissimus muscle from beef cattle injected with hydrogen peroxide. The 74th Reciprocal Meat Conference of the American Meat Science Association

**Mississippi (Dinh), Nebraska (Calkins), and Texas (Miller):** Meat research has focused on three main areas. These are the relationship of oxidative stress to meat tenderness, beef color during frozen storage, dry aging, and the impacts of vitamin E supplementation on dry aged beef.

**Nebraska (Sullivan) and Oklahoma:** Research to understand the color change in raw beef caused by high pressure processing.

**Idaho (Bass and Colle), North Dakota (Maddock), Texas (Savell, Griffin, Lawrence, Tennant, Lucherk), Florida (Carr), Georgia (Pringle), Colorado (Morgan and Edwards-Callaway), Oklahoma (Mafi and Pfeiffer), Illinois (Harsh), Kansas (O’Quinn), Ohio (Garcia), and South Dakota (Underwood):** 2021 National Beef Quality Audit.

**Idaho (Bass and Colle), Indiana (Kim), and Texas:** Evaluating metabolomics and flavor compounds in dry aged beef.

**Kentucky (Suman) and Mississippi (Dinh):** Recent oxidative stress, muscle proteomics, meat quality collaborations.

* Dinh, T., Li, S., Chen, J., Zhu, H., & Suman, S. P. (2021). Post-translational modification of myoglobin in post-rigor longissimus lumborum muscle from beef cattle injected with hydrogen peroxide. The 74th Reciprocal Meat Conference of the American Meat Science Association.

**Tennessee (Thompson, Myer, Martinez, and Kojima), Michigan (McKendree), Kansas (Tonsor), Kansas (Pendell), and Mississippi (Maples):** These collaborations were related to several projects with continued ongoing efforts. These projects include multiple outcomes related to the effects of COVID-19 on the beef and agricultural supply chain. Outcomes included peer-reviewed publications, presentations, and outreach efforts:

1. Anderson, J., D. Anderson, D. Brothers, J. Dorfman, K. Guidry, J. E. Holmes, **J. Maples**, **J. Thompson**, and J. Worley. “Estimate of Economic Losses by Contract Growers in the Poultry Sector due to COVID-19.” Staff Paper. SP012020. University of Arkansas. 2020.
2. **Martinez, C**., **J. Maples**, and J. Benavidez. "Beef cattle markets and covid‐19." *Applied Economic Perspectives and Policy* 43.1 (2021): 304-314.
3. **Maples, J.**, **J. Thompson**, J. Anderson, and D. Anderson. “Estimating COVID-19 Impacts on the Broiler Industry.” *Applied Economic Perspectives and Policy.* 43(1). 2021.
4. Weersink, A., M. Von Massow, N. Bannon, J. Ifft, **J. Maples**, K. McEwan, **M. McKendree**, C. Nicholson, A. Novakovic, A. Rangarajan, T. Richards, B. Rickard, J. Rude, M. Schipanski, G. Schnitkey, L. Schultz, D. Schuurman, K. Schwartzkopf-Genswein, M. Stecphenson, **J. Thompson**, and  K. Wood. “COVID-19 and the Agri-Food System in the United States and Canada.” *Agricultural Systems.* 188. 2021.
5. **Thompson, J**.**M**., **D.L. Pendell**, A.D. Hagerman, and K.K. Johnson. “International Trade Implications of Highly Pathogenic Poultry Disease Events.” *Agricultural and Resource Economics Review*. 49(3). 2020.

1. **Accomplishments**

**California – Fausti:** In the third year of this regional project, I have focused my efforts on making progress toward achieving the milestones outlined in objectives 1 and 2 of the W-4177 project proposal. Currently, I have finished my investigation of how ground beef and bison Meat-Eating-Quality (MEQ) attributes affect consumer market valuation of these products.

**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.

**California – Vahmani:** Vahmani’s contribution to the project is in the area of Objective 3: “Improve nutrient profile of beef and identify constituents of beef that influence flavor and healthfulness. Create knowledge on the relationship between human disease mechanisms and the nutritional profile of red meat.” The PI is studying how rumen-derived fatty acids including trans fatty acids affect beef quality and healthfulness. The PI is currently investigating the effects of beef trans fatty acids on adiposity, insulin and glucose homeostasis and inflammation in diet-induced obese/diabetic mice. The PI is also investigating how different beef production systems/feeding strategies influence content and profiles of trans fatty acids in beef.

**California – Yang:** The project we have completed was to evaluate the effect of different feeding systems on the safety and quality of beef in California. The findings of the project provide valuable information on the pathogen prevalence, palatability and shelf life of beef from cattle raised under grass- and grain- based production systems. A comprehensive assessment of these systems' respective microbiomes helped producers to determine what safety measures and precautions must be taken to minimize possible pathogenic risks that may arise throughout the beef production chain. The results about the sensory and shelf life of beef derived from animals fed in different production systems also can be used for consumer education and beef products promotion.

**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. Research was undertaken to examine the effect of electrical stimulator voltage settings on beef longissimus tenderness. Additionally, research was undertaken to compare and validate different colorimeters for measuring meat color. In addition, a comprehensive evaluation of the nutrient composition of the traditional animal-based proteins and novel-plant based products was conducted.

**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 carcass quality, tenderness, color, postmortem enzymatic activity, 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. Research into commercial dry aged beef facilities were investigated for palatability differences amongst microbiomes. Findings of the dry-aging research led to the development of a trained dry-aged beef taste panel which evaluated the boldness of flavors within different commercial dry-aged beef locations. Initial research has been conducted evaluating the Meat Imaging Japan (MIJ) portable beef carcass grading camera.

**Kansas – Pendell:** The research projects directly contributed to objectives #4. The outcomes provide a better understanding of the costs and benefits of: animal identification/ traceablity; and mitigation strategies of Johne’s in beef cattle. This could assist with designing policies that encourage more adoption of animal ID and various Johne’s mitigation strategies by cattle producers.

**Kansas – Chao:**

1. Evaluating the effect of anti-phospholipase a2 antibody to extend meat shelf-life in a beef liposome model system
2. Investigating the role of native beef collagenase on postmortem collagen degradation and beef tenderness
3. Proposing an ELISA method to evaluate elastin content in beef shank and understanding elastin contents effect on beef shank tenderness

They are related to project objective 1:

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.

**Kansas – Tonsor:** Testimonies in 2021 to the Kansas House Ag. Committee and U.S. Senate Ag. Committee in-part build upon this research. The Meat Demand Monitor, funded in part by the Beef Checkoff, continues to provide a host of domestic beef demand insights.

**Kentucky – Suman**

Dietary ractopamine causes a muscle fiber shift in cattle, and the biochemistry of mitochondria in postmortem muscles is influenced by fiber type. Nonetheless, the influence of ractopamine on beef skeletal muscle mitochondrial proteome has not been evaluated. Therefore, the objective of this study was to examine the effects of dietary ractopamine on mitochondrial proteome of postmortem longissimus lumborum (LL) from feedlot crossbred steers. Pen-housed crossbred steers were fed either a corn-based basal diet (CON) or a diet top-dressed with Optaflexx 45 (Elanco Animal Health) to provide 400 mg of ractopamine hydrochloride/steer per day (RAC). Ractopamine was fed the last 28 days prior to the harvest. The LL muscle samples were obtained from nine (n = 9) RAC and nine (n = 9) CON carcasses. The mitochondrial proteome was analyzed using two-dimensional gel electrophoresis and mass spectrometry. Seven differentially abundant proteins (P < 0.05) were identified. Three proteins over-abundant in RAC were complement component 1 Q subcomponent-binding protein (C1QBP), very long-chain specific acyl-CoA dehydrogenase (ACADVL), and aconitate hydratase (ACO2). On the other hand, four proteins, ATP synthase subunit beta (ATP5B), prohibitin (PHB), cytochrome b-c1 complex subunit (UQCRC1), and thioredoxin-dependent peroxide reductase (PRDX3), were over-abundant in CON. The differentially abundant proteins belong to four functional groups – energy metabolism (ATP5B, UQCRC1, and ACO2); chaperone activity (C1QBP and PHB); antioxidant (PRDX3); and fatty acid degradation (ACADVL). The increased protein synthesis and leanness reported in ractopamine-fed cattle may be attributed to the increased expression of enzymes involved in fatty acid degradation and the decreased expression of enzymes involved in oxidative phosphorylation. Additionally, the decreased tenderness previously reported in beef from ractopamine-fed cattle may be attributed to the increased expression of antiapoptotic protein (C1QBP) and decreased expression of proapoptotic protein (PHB) resulted from ractopamine supplement.

**Mississippi – Dinh**

* Completing the oxidative stress study on beef cattle and the proteomic analysis of longissimus muscle, and the report to the MSU MAFES, publishing 5 abstracts, preparing 2 manuscripts.
* Focusing on beef flavor compounds, obtaining funding from NIFA to study water-soluble compounds in beef, collaborating with Dr. Colle from University of Idaho to research post-mortem changes in flavor compounds due to electrical stimulation.
* Conducting various analyses in collaboration with Dr. Calkins at UNL and industry partners on beef quality and composition

**Nebraska – Calkins and Sullivan:** UNL activities: Calkins has collaborative research with Mississippi and Texas A&M University. Meat research has focused on three main areas. These are the relationship of oxidative stress to meat tenderness, beef color during frozen storage, dry aging, and the impacts of vitamin E supplementation on dry aged beef. Sullivan has focused on safety of sous vide cooked beef, survival and growth of Pseudomonas in beef products, and spoilage of beef products during extended storage. Additional work has been conducted to understand the color change in raw beef caused by high pressure processing in collaboration with Oklahoma State University. Research funding was secured from the Nebraska Beef Council.

**Nevada – De Mello:** De Mello conducted several projects to optimize the application of food processing aids to control *Salmonella* in ground beef to prevent food-borne illnesses. Regarding quality attributes, projects were conducted to understand the effects of dry aging on Prime, Choice, and Select beef. De Mello also conducted research to identify novel genetic biomarkers for beef quality traits and initiated investigations to identify the epigenetic role of beef-derived RNAs on human health.

**North Dakota – Maddock:** Research in 2020 was difficult due to COVID restriction as our intended projects required access to beef processing facilities or retail stores. Manuscripts and abstracts were published or made ready from previous work.

Proposals were submitted to continue research in the area of beef quality and along with numerous collaborators the 2021 National Beef Quality Audits were planned and the 2021 National Beef Tenderness Survey was planned.

**Indiana – Brad 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. In this reporting period, Dr.Kim’s group worked on a couple of beef projects – 1) NCBA funded fresh beef tumbling and 2) continue working on USDA-AFRI grant – cull cow dry-aging projects.

Numerous strategies have been employed to accelerate the tenderization process through physical disruptions to muscle structure and/or endogenous proteolytic enzymes. However, there exists a pressing need for developing natural post-harvest processing systems that produce beef products with improved eating quality attributes, given the growing consumer demand for natural/minimally processed fresh meat products. Simple tumbling of vacuum packaged fresh meat sections without the use of brines may represent a feasible natural means of improving fresh beef quality and palatability. The objectives of this study were to (1) demonstrate feasibility of the tumbling of vacuum packaged fresh beef on improving quality attributes and proteolysis of beef *M. Longissimus lumborum* muscles, (2) evaluate the combined tumbling and aging process of varying durations on quality and consumer palatability of beef *M. Longissimus lumborum* and *M. Semitendinosus*, and (3) utilize the optimal tumbling duration to improve quality attributes across three beef sirloin muscles (*M. Gluteus medius, M. Biceps femoris*, and *M. Tensor fasciae latae*)

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, we identified flavor-related chemical compounds that positively impact meat quality attributes of dry-aged loins from cull cow along with descriptive sensory analysis.

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

Basic and applied research was conducted to examine

* willingness to pay to invest in biosecurity related to animal disoposal 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
* 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
* Understanding the impact of the rumen microbiome on beef cattle performance
* Understanding the impact of the rumen microbiome on beef cattle performance
* Effects of rumen content exchange on bacterial community dynamics and production-relevant parameters
* The effects of a moderate and aggressive implant strategy on the ruminal microbial community and metabolome in steers
* The factors impacting feeder cattle prices. Specifically, cattle that have been tested for Persistently Infected with Bovine Viral Diarrhea
* examining the influence of farm demographics and producer perceptions on cow-calf producer horn fly (diptera: muscidae) management costs in Tennessee and Texas.

These efforst 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.

This 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.

1. **Short-term Outcomes**

**California – Fausti:** Data collected from a combined willingness to pay panel and a consumer sensory panel experiment involving ground beef and ground bison have been analyzed.

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

**California – Vahmani:** Research conducted in Vahmani lab showed that trans10-18:1 is consistently the predominant trans fatty acid in beef from cattle finished on grain-based diets, while trans11-18:1 is consistently the predominant trans fatty acid in beef from cattle finished on forage-based diets. Preliminary findings from the mouse study indicates that feeding a high fat diet containing beef fat biofortified with trans-11 worsens insulin resistant and liver steatosis compared to mice fed a high fat diet containing an equivalent amount of cis fatty acids (oleic acid). In addition, the PI has developed a chemical procedure to synthesize enough quantities of purified trans10-18:1 (predominant trans fatty acid in grain-fed beef) and trans11-18:1 (predominant trans fatty acid in grass-fed beef) and has started testing their health effects/bioactivities in animal model and cell culture studies.

**California – Yang:** All tested feeding systems resulted in the same level of reduction from baseline to harvest in prevalence of general STEC and acid-resistant STEC. Fecal bacterial communities from GR45 and 20GF cattle had decreased alpha diversity at harvest while fecal microbiotas of CON and 25GF cattle did not. Rapid shifts in the diets of GR45 cattle from grass-based to grain-based diets decreased alpha diversity and centralized fecal microflora toward Proteobacteria and key Firmicutes genera. No association between phyla or genera abundances and fecal STEC population or prevalence was observed. Age may play a more important role in Proteobacteria abundance than feeding system, and may warrant further study of the effects of age on Proteobacteria abundance in beef cattle.

Steaks from the 20GF and 25GF groups were darker in color while steaks from the CON and 25GF groups were redder and had lighter fat color. Consumers rated steaks from the CON group higher in all attributes (tenderness, juiciness, and flavor) and overall acceptance than those from the 20GF or 25 GF groups. However, steaks from the CON group had a much higher lipid oxidation rate. Microbial results showed that steaks from the GF20 group had higher initial microbial counts and spoiled more quickly than those in the CON group.

**Colorado – Belk and Nair:** Our studies on electrical stimulator settings indicated that there is variations in low voltage electrical settings does not influence beef tenderness. Comparison between novel Nix colorimeter and HunterLab colorimeter suggested that Nix is a comparable alternative for measuring beef color, whereas nutritional comparison of animal and plant proteins indicated the variations between different protein sources.

**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. Merchandising research utilizing an online survey has demonstrated distinct willingness to purchase differences between the two cuts. Dry aging microbiome work has demonstrated that the microbiome of molds and bacteria of different commercial dry-aging facilities is indeed different. Differences in environment demonstrate unique dry-aging conditions resulting in distinctly different microbial populations on dry-aged beef. Flavor boldness has also been shown to be different among commercial dry-aging facilities. Rosemary extract and acerola cherry powder are effective antioxidants for extending the color stability of beef chuck rolls and short ribs and has led to follow-up research opportunities. Moreover, the MIJ portable beef grading camera prototype demonstrated a strong correlation to currently used camera vision beef grading technologies.

**Kansas – Pendell:** Three completed graduate students are employed and contributing to the beef industry in meaningful ways, including: 1) educating the future generation of agricultural student leaders, 2) consulting on projects that are directly tied to the beef industry (e.g., traceablity), and 3) is a large cattle producer and consulting veterinarian. Another outcome: one of the projects is being used to help develop an educational outreach program concerning grazing management plans for cattle producers.

**Kansas – Chao:**

1. The anti-phospholipase A2 has shown to prevent lipid oxidation in the beef liposome system, which may be able to improve beef shelf-life when applied to whole muscle products.
2. Collagenases such as matrix metalloproteinase -9 have shown to play a role in softening connective tissue texture during aging.
3. An enzyme linked immunosorbent assay has been tested and may be used to estimate elastin content in beef.

**Kentucky – Suman**

The innovative data from this work indicated that dietary ractopamine modulates beef muscle proteome and thus can impact meat quality.

**Nebraska – Calkins and Sullivan:** A dry aged beef workshop was hosted for industry personnel and students with speakers from W-4177 Multi-state research committee from University of Nebraska and University of Idaho. Poster presentations spoilage of beef during extended storage, safety of sous vide cooking of beef steaks, vitamin E supplement were included presented as a poster at the Reciprocal Meat Conference.

**Nevada – De Mello:** de Mello demonstrated that applications of phages either on trim, coarse, and fine ground lead to similar reductions in ground beef. Recommendations were provided to the industry to apply phage on coarse ground to decrease the waste of phage solutions as observed during applications on trim. de Mello showed that major effects on meat quality in aged beef are due to levels of fat content and not aging methods. However, dry aging seems to improve acceptability of Select-graded beef when is performed for 21 days. Long aging periods (80 d) increase off-flavor, especially livery in wet-aged and sour and bitter in dry-aged. De Mello also conducted a project to improve American veal quality and observed that supplementing calves with diets containing omega 3s and starch improve their health and carcass weight. Most recently, research conducted in NV suggested that genes modulating calpain and calpastatin are not the best biomarkers for meat tenderness but other 42 genes associated to other metabolic pathways and 19 microRNAs (miRs) directly correlated with post mortem proteolysis. From a nutrition stand point, de Mello demonstrated that beef-derived miRs resist to digestion and may be absorbed in mice intestines.

**North Dakota – Maddock:** We have presented information that carcass size is not highly related most meat quality attributes. Specifically, There were no differences in drip loss, cook loss or WBSF in either longissimus thoracis or semimembranosus muscles (P ≥ 0.10) among carcass groups. Objective color measurements found steaks from heavy weight carcasses were redder than steaks from light weight carcasses (P ≤ 0.02). Hot carcass weight group did not influence most meat quality attributes of steaks with the possible exception of color.

In addition, we investigated and reported how various direct and derived measurements beef carcass temperature decline were related. For longissimus (LT) and semimembranosus (SM), derived slope of the temperature decline curve was not significantly correlated with other temperature measures (r ≤ 0.42, *P* ≥ 0.08). In the LT and SM, 8 h and 12 h time points were significantly correlated with other temperatures (0, 4, 6, 8, 12, 16, 20, 24 h, AUC 6 h, and AUC 24 h) (r ≥ 0.54, *P* ≤ .0001). In the LT, 20 and 24 h temperature measures were significantly correlated to 12th rib back fat thickness (r = 0.50, *P* = 0.0001, r = 0.52, *P* = <.0001, respectively). Conversely, in the SM, 12, 16, 20, and 24 h temperature measures were significantly correlated to hot carcass weight (r ≥ 0.37, *P* ≤ 0.0089). Our results indicate the 8 and 12 h time points have the highest correlations with other temperature decline data, and can be used to describe temperature declines in beef carcasses during chilling.

**Mississippi – Dinh**

***Oxidative stress muscle proteome - abstract***: Overall, more residues were modified and a greater number of PTM were found in OX myoglobin (32/47, respectively) than in CON myoglobin (33/56, respectively). Phosphorylation occurred on serine and threonine residues in both CON (9 PTMs) and OX (9 PTMs); whereas tyrosine was phosphorylated only in CON. Methylation, acetylation, and carboxymethylation were detected in lysine and arginine residues in both CON (14/6/10 PTMs, respectively) and OX (12/10/12, respectively). The 4-hydroxynonenal alkylation of histidine and lysine residues occurred more in OX myoglobin (13 PTMs) than in CON myoglobin (8 PTMs). Moreover, 4-hydroxynonenal alkylation of distal histidine (His 64), responsible for heme stability, occurred only in OX myoglobin. The 4-hydroxynonenal modification of His 64 was particularly concerning because it is an indicator of myoglobin oxidation, which makes myoglobin less sensitive to metmyoglobin reductases. Post-translational modifications of myoglobin compromise myoglobin redox stability and fresh beef color stability. These findings suggest that myoglobin PTM in postmortem skeletal muscles may be exploited as biomarkers of pre-harvest oxidative stress in beef cattle.

***Electrical stimulation (ES) of beef muscles – abstract***: Two-way treatment × day interactions were found for glutamic acid and asparagine in SM (P < 0.001). Glutamic acid remained similar among treatments on d 1 and 4; however, it was increased by 213 to 247 nmol/g on d 14 by early ES compared with early NS (P < 0.001). Asparagine followed a similar pattern with an increase of 20 to 28 nmol/g by early ES on d 14 (P ≤ 0.048) compared with early NS. Other free amino acids in SM, including the most predominant ones, were influenced only by day with d-14 content being the greatest (P ≤ 0.023). In the LL, only day effect was found for 18 amino acids (P ≤ 0.038), including those related to desirable flavors such as glutamic acid (umami) and glycine (sweetness). Early electrical stimulation influenced the free amino acid content in the SM muscle more than that in the LL muscle. However, aging increased the content of most amino acids across treatments and muscles. These findings suggest that both electrical stimulation and aging can be used to alter the content of water-soluble flavor compounds in beef, which, in turn, influence beef flavor and consumer acceptance.

**Indiana – Brad Kim:** Overall, the results suggest the fresh beef tumbling without brine addition has a considerable improvement in tenderness of *M. Longissimus lumborum* muscles, while the improvement is less substantial for muscles originating from the sirloin and *M. Semitendinosus*. This translated to consumers finding tumbled beef *M. Longissimus lumborum* muscles to be more tender than T0 controls regardless of aging duration with no detriment to juiciness or flavor. Simple tumbling at lower speed resulted in immediate about 38% decreases in WBSF without further aging. While WBSF values were equivalent, there was a strong trend of improved liking of tenderness of tumbled and aged *M. Semitendinosus* muscles. Proteolysis results supported that tumbling disrupted muscle structure and degraded myofibrillar protein, although the impact of further aging was more substantial for degradation of myofibrillar proteins in most muscle types. Trained panel evaluators found no improvement in tenderness in *M. Biceps femoris* and *M. Tensor fasciae latae* muscles, finding them poorer for juiciness. However, the *M. Gluteus medius* was found to have superior myofibrillar tenderness with tumbling, in agreement with WBSF data, with no detriment to overall juiciness.

For our cull cow dry-aged beef study, volatile analysis indicated that dry-aging generated more volatile compounds, especially from hydrocarbon and alcohol groups, compared to wet-aged counterparts. Additionally, more sulfur containing compounds, such as thioproline and erysothiopine, were observed in dry-aging treatments compared to wet-aging control. Sulfur containing compounds have been often related to desirable flavor in beef product. Trained panel identified that dry-aged steaks had significantly lower fat and sour flavor and a trend of lower oxidized flavor (*P=*0.07) compared to steaks from WA and UDA. Consumer panel, however, found no differences in sensory attributes between treatments (P>0.05). This observation potentially indicates that different post-harvest aging methods could affect the liberation of flavor related compounds of beef. Further research correlating these compounds to sensory quality and conducting pathway analyses to elucidate the underlying mechanisms by which dry-aged beef flavor-related compounds can be generated is currently underway.

**Tennessee – Thompson, Myer, Martinez, 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. Multiple analyses of how COVID-19 impacted the beef and related secotrs including poultry. These analysis showed the substantial impact on the supply chain, markets, prices, transportation, and consumers. Related trade effects were estimated.

To better understand on farm mangement techniques and how decisions impact profitability, a dataset was collected on feeder calf prices in Tennessee ranging from 2015-2020. A hedonic model was employed to examine factors impacting feeder cattle prices. Amongst the results, cattle that have been tested for Persistently Infected with Bovine Viral Diarrhea sold for a premium of $1.20/cwt. The data set will continue to incorporate sale data over time, which will provide accurate estimations of premiums asscociated with their cattle when they market them.

Furthermore, a survey was employed to analyze costs associated fly management. Specifically, the influence of farm demographics and producer perceptions on cow-calf producer horn fly (diptera: muscidae) management costs in Tennessee and Texas. It was found that fly management costs were lower in Tennessee by appromitely $3/head.

Regarding Rumminant 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.

1. **Outputs**

**California – Fausti:** A poster was presented the AAEA annual meeting in Kansas City MO. The meeting was held in July, 2020. Conference presentation was published on AgEcon Search: https://ageconsearch.umn.edu/record/304410. Manuscript has been written and submitted to refereed journal.

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

**California – Vahmani:** Vahmani has published 5 articles in peer-reviewed journals and 2 abstracts at professional meetings.

**California – Yang:** Frederick Yang, M.S. graduated.

F. Yang, S. Klopatek, J. Oltjen, X. Yang. 2021. The Fecal Microbiota and Shiga toxin-producing Escherichia coli Population and Prevalence Differed in Beef Cattle Raised Under Conventional Grain-fed and Grass-fed Feeding Systems in Northern California. *Submitted to Frontiers in Microbiology*.

T. Duarte, B. Bolkenov, L. Yang, S. Klopatek, J. Oltjen, X. Yang. 2021Evaluating Shelf-life and Consumer Acceptance of Beef Steaks from Cattle Raised on Different Grass and Grain Feeding Systems in California. *In preparation*.

**Colorado – Belk and Nair:** Two book chapters, 4 referred journal articles, and 7 abstracts were published. Nair received the Achievement Award - American Meat Science Association Annual Reciprocal Meat Conference Reno, NV, 2021. Four grants were funded for over $200,000. Three graduate students finished their M.S. Degrees.

**Idaho – Bass and Colle:** Since the 2020 Hatch W4177 meeting Idaho published 4 peer-reviewed manuscripts and 9 abstracts; all related to beef quality and improvement. 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.

**Kansas – Pendell:**

Leigh Rosengren – Masters of Agribusiness, Finished June 2021.

Cassie Aherin - Masters of Agribusiness, Finished March 2021.

Hannah Shear – Ph.D., Finished July 2021.

**Kansas – Coffey:** Outputs include one completed M.S. Thesis, on peer reviewed journal article, one invited presentation, and one manuscript submitted.

**Kansas – Chao:** Chao published 3 journal articles and 7 abstracts. Two grants were funded for over $130,000. Chao was also an invited speaker: Reciprocation Session, Reciprocal Meat Conference (RMC), “Using Collagen Crosslinks as a Marker to Predict the Sensory Attributes of Lower Quality Beef Cuts”, August, 2021, Reno, NV.

**Kansas – Tonsor:** Outputs include 9 journal articles.

**Kentucky – Suman**

Yifei Wang (MS Student with Dr. Suman) received 1st place in the Graduate Student Research Poster Competition (M.S. Division) of American Meat Science Association.

Yifei Wang (graduate student with Dr. Suman) graduated with MS (2020) at the University of Kentucky.

Dr. Surendranath Suman was recognized as University Research Professor (2021) at the University of Kentucky.

**Mississippi – Dinh**

* 2 Ph.D. students, 1 M.S. student
* 6 abstracts published
* 2 manuscripts being prepared
* 3 grant proposals, 1 funded, 2 unfunded

**Nebraska – Calkins and Sullivan:** Outputs directly related to this project include 8 peer reviewed manuscripts, 7 University research reports, 7 scientific meeting abstracts, and 2 theses.

**Nevada – Amilton de Mello:** In 2020: Published 4 journal articles and 3 conference abstracts. De Mello was awarded the University of Nevada, Reno Cooperative Extension Outstanding Faculty in 2020, received a 4H service award, was reappointed as a member of the USDA-NACMPI, and developed 3 informative videos for the USMEF to promote American Beef in South America.

**North Dakota – Maddock:** One manuscript and two abstracts have been published.

One graduate student competed a M.S. and started a Ph.D. and two undergraduate students participated in research projects.

**Indiana – Brad Kim:** Published several peer-reviewed articles and presented research abstracts/proceeding papers. Served as invited speaker at regional and international scientific meetings/seminars. Trained 3 PhD and 1 MS students, 4 visiting scholars and 2 undergraduate students for their research projects

**Tennessee – Thompson, Myer, Martinez, and Kojima:** Fifteen referred publications, 14 presentations, one congressional report, 15 extension publications, and four conference proceedings were published. One M.S. student finished their degree. Four grants were received totaling over $6,000,000.

1. **Activities**

**California – Fausti:** Currently, research activities have returned to investigating price discovery issues in the fed cattle market.

**California – Vahmani:** Multiple research projects were conducted looking at factors influencing trans fatty acid composition and content of beef fat. Currently, a M.S. student is also researching the effects of beef-derived fatty acids on insulin and glucose homeostasis using a high-fat-diet fed mouse model.

**California – Yang:** Post-weaning beef steers were blocked by weight and randomly assigned to four treatment groups by feeding system: (1) Conventional grain-fed (CON, n=22), (2) 20-month grass-fed (20GF, n=17), (3) grass-fed then grain finished for 45 days (GR45, n=13), (4) 25-month grass-fed (25GF, n=16). Rectal fecal samples from the cattle were collected at 14 months of age as baseline prior to the assignment of treatment groups, and were collected again one week before each treatment group’s harvest date. Presumptive STEC isolates were cultured from fecal samples to determine the levels of STEC populations and their prevalence. The DNA of all fecal samples were extracted and sequenced for 16S rRNA gene for microbiota analysis.

Following harvest, striploins were collected and aged for 14 days before being cut into steaks, packaged, and placed either into a retail display case for a 6 day period for shelf life study or frozen for further analysis. Every 12 hours during retail display, instrumental color (CIE L\*, a\*, and b\*) of lean muscle and external fat surfaces were measured. On days 0, 3, and 6, bacterial counts (AMB, APB, and LAB), and pH were measured. Lipid oxidation was determined using the thiobarbituric acid reactive substrates (TBARS) analysis for samples stored at the end of retail display (Day 6). Steaks frozen for further analysis were thawed and used for objective tenderness (WBSF and SSF) and consumer sensory evaluations.

**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 7 graduate and 12 undergraduate students in Meat Science.

**Kansas – Pendell:** One of the projects evaluated the costs of CattleTrace animal identification system. Specifically, we evaluated the costs at each segment of the supply chain in the beef industry (e.g., cow-calf, stocker/background, sale barn, feedlot, and packer.

Another project looked at the financial impacts of Johne’s in beef herds. Specifically, an agent based model simulated the epidemiology impacts of Johne’s and evaluated different mitigation strategies. Partial budgets and net present value were used to evaluate the financial impacts of the different mitigation strategies.

With the term ‘sustainably’ being a hot topic in the beef industry, we evaluated one component of sustainability, grazing management. Specifically, we surveyed cattle producers across the U.S. to better understand grazing management plans.

**Kansas – Chao:** Conducted research activities including:

1. Sample collection and preparation
2. Tenderness assessment, color and water holding capacity
3. Assessment
4. Consumer and trained panels
5. Proximate and pH analysis
6. Lipid oxidation analysis
7. Sarcomere length measurement
8. Protease activity measurement
9. Thermal analysis of connective tissue
10. Collagen crosslink density measurement
11. Protein degradation analysis
12. Data analysis and the dissemination of findings

**Nebraska – Calkins and Sullivan:** Calkins conducted a dry-aged beef workshop. Multiple research projects were conducted on the topics of the relationship of oxidative stress to meat tenderness, 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, blade tenderization, and dietary vitamin E supplementation on dry-aged beef was obtained. Research projects were conducted evaluating the survival and growth of *Pseudomonas* in vacuum packaged cooked beef, the control of *E. coli* and *Salmonella* in sous vide cooked steaks using different temperatures and holding times, and impacts of antimicrobial interventions on microbial population and of beef. Investigations on improving the color stability of raw beef treated with High Pressure Processing were conducted.

**Nevada – Amilton de Mello:** In 2020: Developed researchapproaching the objectives 3 and 4 of this project, trained 3 graduate students and served as a member for the USDA National Advisory Committee on Meat and Poultry Inspection.

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

Funding was obtained to conduct research investigating how carcass size, weight, and fatness affects postmortem muscle metabolism and beef quality. Research will start in October 2021.

**Indiana – Brad Kim:** In this reporting period, Dr. Kim was invited to give special presentations at several universities and national institutes in Korea past summer and a virtual presentation at the regional meeting in Indiana. Some of the results of the current projects were also disseminated through online media coverage such as American Association of Meat Processors and Meatingplace besides peer-review journal article publication. Kim lab graduate students (Derico Setyabrata, Jacob Tuell, and Mariah Nondorf) attended the 2020 ICoMST/RMC virtual meeting to present some of findings of the current projects and to participate in the graduate research competition in the PhD/MS division. Jacob placed Second Place in the Phd division and Mariah won the First Place in the MS division graduate competition. Also, Anna Wagner received the Second Place in the undergraduate research poster competition at the 73rd annual RMC meeting.

Dr. Kim served as a co-chair of 2020 ICoMST/RMC Program Abstract Committee. He’s been serving as an honorary scientist and advisor of National Institute of Animal Science, Korea, international editor of Food Science of Animal Resources journal, and editorial board member of Meat and Muscle Biology, Food Chemistry, Food Chemistry Advances, and Applied Science journals.

**Kentucky – Suman**

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.

**Mississippi – Dinh**

* Analytical technique training: GC-MS, LC-MS, flavor compound extraction
* Sensory evaluation of beef flavor
* Proteomic analysis
* Data analysis and scientific writing (abstracts, presentation, manuscripts)

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

For the Ruminant Health projects, this multi-state project permitted the attendance to numerous annual meetings: The American Society of Animal Science Annual Meeting, the American Society of Animal Science Southern Section meeting, the World Microbe Forum, to name a few. Conferences were attended to promote research regarding the outcomes of this project, which were disseminated by graduate students in the program and the project director.

For the Ruminant Health projects, this multi-state project has also aided in the training and development of six graduate students who are currently enrolled or have graduated from the current research program and actively participated in the project. Due to the multi-faceted nature of the project, the students are active in laboratory/bench research, light bioinformatics, physical sampling and animal handling, data and statistical analyses, and research manuscript preparation.

1. **Milestones**

**California – Fausti:** Completed Beef Versus Bison Willingness to Pay study. Provided empirical evidence of the linkage of consumer sensory panel data to consumer WTP bidding behavior in experimental auctions.

**California – Vahmani:** Vahmani developed a new method for predicting beef carcass fatty acid composition using blood samples from feedlot cattle. Research continues in the area of beef fatty acids with a project initiated to compare bioactivities and health effects of trans10-18:1 (predominant trans fatty acid in grain-fed beef) vs. trans11-18:1 (predominant trans fatty acid in grass-fed beef).

**California – Yang:** Cattle fecal samples were collected. STEC prevalence, population and acid-resistance STEC was determined. Microbial DNA was extracted and sequenced on Illumina MiSeq for 16S rRNA genes. Sequence data were analyzed to characterize the microbiome.

Strip loins were collected after cattle were slaughtered. Steaks were cut and packaged. The pH, spoilage bacterial counts, TBARs, instrumental colors, objective tenderness were measured. Consumer tasting panels were conducted.

**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:** Phil Bass and Michael Colle both continue on a positive trajectory toward tenure status at the University of Idaho. Combined, Dr. Bass and Dr. Colle have been able to secure external funding for a variety of meat quality related projects totaling $240,785.

**Kansas – Pendell:** All three projects described above were completed in the past year. All three students successfully complete their degrees. One of the projects resulted in a peer review publication and two additional manuscripts are currently being developed.

**Nebraska – Calkins and Sullivan:** Calkins gave an invited presentation on Digital Image Sensing on Beef Quality during a con-current session at the American Meat Science Association Reciprocal Meat Conference.

**Nevada – Amilton de Mello:** In 2020: Applications of phage solutions as processing aids are efficient when added during grinding. Feeding omega 3 and starch to calves improves veal quality. Volatile profile of aged beef differs within aging method, aging length and USDA grade. Beef microRNAs can be absorbed in mice intestines suggesting that can also be absorbed by humans.

**North Dakota – Maddock:** No other milestones to report.

**Indiana – Brad Kim:** Dr. Kim and his collaborators are currently working on conducting the last 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 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.

**Kentucky – Suman**

We have characterized the effects of dietary ractopamine on mitochondrial proteome of postmortem longissimus lumborum from feedlot crossbred steers.

**Mississippi – Dinh**

* Completion of a preliminary study on oxidative stress in beef cattle
* Collaboration with other scientists in oxidative stress (Suman – Kentucky) and beef flavor (Colle – Idaho)
* Collaborative grant proposals are being prepared.

**Tennessee – Thompson, Myer, Martinez, and Kojima:** Milestones include dissemination to multiple, disciplinary and crossdisciplinary 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 studnts and those from Zamorano University.

1. **Impact Statements**

**California – Fausti:** Long term goal is to add to the understanding of how consumer preferences for beef is linked to consumer purchasing behavior by documenting the linkage between consumer sensory panel preferences and consumer WTP bidding behavior in experimental auctions.

**California – Vahmani:** The trans fatty acid composition and content of beef fat are becoming more of interest as partially hydrogenated vegetable oils (industrial trans fats) are removed from the food supply, and as ruminant-derived foods become the major source of trans fatty acids in human diets. Our long term goal is to figure out which rumen-derived trans fatty acids are healthful and which ones are detrimental so we can develop feeding strategies to maximize beneficial fatty acids and minimize detrimental ones in beef. Findings from our research will help direct future efforts to enhance the nutritional value of beef, and will ultimately help to enhance the competitiveness of nutritional value the US beef.

**California – Yang:** The next goal of my program is to investigate antimicrobial resistance in beef cattle production using metagenomics and bioinformatics to combat antimicrobial resistance.

**Colorado – Belk and Nair:** The research conducted at Colorado State University will improve our understanding of postmortem metabolism and beef quality development, especially of quality parameters such as color, tenderness, and flavor.

**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.

**Kansas – Pendell, Chao, Tonsor:** The long-term goals are:

* Expand research collaboration among scientists from other departments and other land-grant universities.
* Enhance knowledge in current meat science and muscle biology research.
* Additional income and job opportunities created to support and sustain the economic viability of American farm operations.

These long-term goals will enhance thecompetitiveness and value of US beef by defining new methods to improve the quality and shelf-life of US 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 on accelerated dry aging was funded for $59,833 (10/1/2019 – 9/39/2020) by the Nebraska Beef Council. Sullivan received a grant on impacts of antimicrobial interventions on microbial communities in beef during extended storage for $57,730 (10/1/2020-9/303/2021).

**Nevada – De Mello:** Applications of phages during grinding minimize contamination caused by accidently grinding lymph nodes harboring *Salmonella*. Increasing veal production in the U.S. by improving dietary management may decrease the presence of imported veal in domestic markets. Traditional genes associated to enzyme activity may not be the best biomarkers for tenderness. Exogenous microRNAs are absorbed in the intestine and may modulate human health.

**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.

**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.

**Kentucky – Suman**

Our long term goal is to identify ongoing market risk associated with domestic livestock protocols to the U.S. beef industry. This strategy could improve quality, safety, and domestic and international marketability of U.S. beef products by examining palatability attributes, increasing shelf life, developing novel products from variety meat items, and developing innovate carcass fabrication techniques.

**Mississippi – Dinh**

We are attempting to characterize oxidative stress in beef cattle, which has been hypothesized to cause many quality issues in beef. We also focus on understanding postmortem metabolism of flavor compounds so that we can improve beef flavor and develop ingredient solutions for beef products.

**Tennessee – Thompson, Myer, Martinez, 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.

1. **Publications**

**California – Fausti:**

1. Economic Evaluation of Consumer Preferences using Experimental Methods: Ground Beef vs. Ground Bison AAEA 2020 Annual meeting conference paper:
2. Fausti, Scott W., Bashir A. Qasmi, Keith Underwood, and Angel Gonzalez. "Economic Evaluation of Consumer Preferences using Experimental Methods: Ground Beef vs. Ground Bison." In 2020 Annual Meeting, July 26-28, Kansas City, Missouri, no. 304410. Agricultural and Applied Economics Association, 2020: https://ageconsearch.umn.edu/record/304410.

**California – Oltjen:**

1. Andreini, EM, SM Augenstein, CD Fales, RD Sainz, JW Oltjen. 2020. Effects of feeding level on efficiency of high- and low-residual reed intake beef steers. Journal of Animal Science 98:(10):skaa286. doi: 10.1093/jas/skaa286
2. Dykier KC, Oltjen JW, Robinson PH, Sainz RD. 2020. Effects of finishing diet sorting and digestibility on performance and feed efficiency in beef steers. Animal 14:59-65. doi: 10.1017/S1751731119001988
3. Fernandez EE, Oltjen JW, Sainz RD. 2020. Mitochondrial abundance and function in muscle from beef steers with divergent residual feed intakes. Animal 14:560-565. doi: 10.1017/S1751731119002209

**California – Vahmani:**

 *Journal Articles*

1. Barragán-Hernández, W., M. E. R. Dugan, J. L. Aalhus, G. Penner, P. **Vahmani**, Ó. López-Campos, M. Juárez, J. Segura, L. Mahecha-Ledesma, and N. Prieto. 2021. Effect of Feeding Barley, Corn, and a Barley/Corn Blend on Beef Composition and End-Product Palatability. Foods. 10(5):977.
2. Juárez, M., S. Lam, B. M. Bohrer, M. E. R. Dugan, P. **Vahmani**, J. Aalhus, A. Juárez, O. López-Campos, N. Prieto, and J. Segura. 2021. Enhancing the Nutritional Value of Red Meat through Genetic and Feeding Strategies. Foods 10(4):872. doi: 10.3390/foods10040872
3. **Vahmani**, D.C.Rolland, H.C.Block, M.E.R.Dugan, and FilippoMiglior. 2020. Red blood cells are superior to plasma for predicting subcutaneous trans fatty acid composition in beef heifers. Can J Anim Sci. 100(3):570-576. doi: 10.1139/cjas-2019-0164
4. **Vahmani**, J.A.Johnson, B.D.Sutherland, G.B.Penner, N.Prieto, J.L.Aalhus, M.Juárez, ÓÓ.López-Campos, M.E.R.Dugan, and FilippoMiglior. 2021. Changes in the fatty acid composition of steer subcutaneous fat, including biohydrogenation products, are minimal when finished on combinations of corn and barley grains and silages. Can J Anim Sci. 101(2):362-369. doi: 10.1139/cjas-2020-0013
5. **Vahmani**, P., E. N. Ponnampalam, J. Kraft, C. Mapiye, E. N. Bermingham, P. J. Watkins, S. D. Proctor, and M. E. R. Dugan. 2020. Bioactivity and health effects of ruminant meat lipids. Invited Review. Meat Science 165:108114. doi: <https://doi.org/10.1016/j.meatsci.2020.108114>

*Abstracts*

1. **Vahmani**, J.A.Johnson, B.D.Sutherland, G.B.Penner, N.Prieto, J.L.Aalhus, M.Juárez, ÓÓ.López-Campos, M.E.R.Dugan, and FilippoMiglior. 2020. substituting corn for barley in beef finisher diets has only minor effects on backfat fatty acid composition. 2020 ICOMST/Reciprocal Meat Conference
2. Juarez, M. M., S. Lam, B. M. Bohrer, M. Dugan, P. **Vahmani**, N. Prieto, O. L. Campos, and J. Aalhus. 2020. Enhancing the nutritional value of red meats through genetic and feeding strategies. 2020 ASAS\_CSAS

**California – Yang:**

1. B. Bolkenov, T. Duarte, L. Yang, F. Yang, B.Roque, E. Kebreab, X. Yang. 2021. Effects of red macroalgae Asparagopsis taxiformis supplementation on the shelf life of fresh whole muscle beef. *Transl. Anim. Sci.*, txab056, <https://doi.org/10.1093/tas/txab056>

**Colorado – Belk and Nair:**

*Book Chapters*

1. Suman, S.P., Ramanathan, R., Nair, M.N. (2021). Advances in fresh meat color stability. *In: New Aspects of Meat Quality: From Genes to Ethics (2nd Edition).* Edited by P.P. Purslow. Elsevier, Oxford, United Kingdom - Submitted
2. Nair, M.N, Zhai C. (2020) Proteomics tools for meat quality evaluation. In *Meat Quality Analysis*. Edited by A. Biswas., P.K. Mandal. Elsevier, Oxford, United Kingdom. Chapter 19, pp 353–368.

*Refereed Journal Articles*

1. Swing, J., Thompson, T.W., Guimaraes, O., Geornaras, I., Engle, T.E., Belk, K.E., Gifford, C.L., Nair, M.N.\* (2021). Nutritional composition of novel plant-based meat alternatives and traditional animal-based meats. *Journal of Food Sciences & Nutrition. 7: 109; doi: 10.24966/FSN-1076/100109*
2. Arp, T.S., Rice, E., Woerner, D.R., Katoh, K., Smith, G.C., Belk, K.E., Nair, M.N. (2021). Electrical stimulator voltage settings minimally influences beef longissimus muscle tenderness. Accepted in *Meat and Muscle Biology.*
3. Schelkopf, C., Rice, E.A., Swenson, J., Hess, A., Belk, K.E., Nair, M.N.\* (2021). Nix Pro Color Sensor provides comparable color measurements to HunterLab colorimeter for fresh beef. *Journal of Food Science and Technology.* 58(9), 3661-3665 <https://doi.org/10.1007/s13197-021-05077-6>.
4. Ramanathan, R., Nair, M.N., Wang, Y., Li, S., Beach, C.M., Mancini, R.A., Belskie, K., Suman, S.P. (2021). Differential abundance of mitochondrial proteome influences the color stability of beef longissimus lumborum and psoas major muscles. *Meat and Muscle Biology*; 5(1): 16, 1-16. doi:10.22175/mmb.11705

**Idaho – Bass and Colle:**

*Peer-reviewed articles*

1. Weber, T.M., B.J. Buseman, J.A. Nasados, J.M. Lancaster, J.B. Van Buren, J.H. Smart, P.D. Bass, G.K. Murdoch, K. Insausti, and M.J. Colle. 2020. Assessing outcomes of genetic selection panels to predict marbling in crossbred beef cattle. *Transl. Anim. Sci.* 4:1-9
2. Lancaster, J.M, B.J. Buseman, T.M. Weber, J.A. Nasados, R.P. Richard, G.K. Murdoch, W.J. Price, M.J. Colle, and P.D. Bass. 2020. Impact of beef carcass size on chilling rate, pH decline, display color and tenderness of top round subprimals. *Transl. Anim. Sci.* 4:1-12
3. Buseman, B.J., T.M. Weber, J.A. Nasados, P.D. Bass, J.B. VanBuren, J.M. Lancaster, J.H. Smart, G.K. Murdoch, W.J. Price, K. Insausti, and M.J. Colle. 2020. Free calcium concentration, calpain-2 activity and final product tenderness of electrically stimulated beef. *Meat and Muscle Biol*. 4(1):24,1-11
4. P.D. Bass. 2021. From trucks to tips – examples of peripheral ways by which the meat industry impacts the United States workforce economy. *Anim. Frontiers* 11(2):36-40.

*Abstracts*

1. Hall, J.B., J. Sprinkle, M. Ellison, S. Goddard, B. Murdoch, J.B. Glaze, P. Bass, and K. Lee. 2021. Comparison of range-based and irrigated cow/calf systems. Idaho Range Livestock Symposium.
2. Lancaster, J.M., J.H. Smart, B.J. Buseman, T.M. Weber, K. Insausti, J.A. Nasados, B. Glaze, W.J. Price, M.J. Colle, and P.D. Bass. 2021. Assessment of dry-aged beef from commercial aging locations across the United States. American Society of Animal Science Midwest Section Meeting
3. Walker-Shira, K.A., B.M. Murdoch, A. Colacchio, K.M. Davenport, M.J. Colle, P.D. Bass, and G.K. Murdoch. 2021. Single nucleotide polymorphisms associated with advanced skeletal maturity in finished beef heifers. American Society of Animal Sciences Meeting.
4. 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. 2021. Extending the shelf-life of beef bone-in short rib steaks using combinations of acerola cherry powder and rosemary extract. Reciprocal Meat Conference, Reno, NV.
5. Wang, S, K.V. To, C. Dahlgren, C. Fornes, H. Hessler, X. Zhang, Y. Campbell, B. Buseman, P. Bass, M. Colle, M. Schilling, and T. Dinh. 2021. Free amino acid content in longissimus lumborum and semimembranosus muscles from electrically stimulated beef carcasses. Reciprocal Meat Conference, Reno, NV.
6. Epperson, B., J. Van Buren, J. Nasados. J. Lancaster, K. Smith, M. Colle, K. Puga, B. Buseman, and K. Insausti-Barrenetxea. 2021. Alternative merchandising strategy of the beef top round. Reciprocal Meat Conference, Reno, NV.
7. Lancaster, J., J. Smart, J. Van Buren, B. Epperson, J. Nasados, W. Price, M. Colle, P. Bass. 2021. Descriptive assessment of dry-aged beef from commercial aging locations across the United States. Reciprocal Meat Conference, Reno, NV.
8. Lancaster, J., M. Colle, B. Epperson, J. Smart, K. Oliver, H. Komine, A. Kano, Y. Sakaguchi, K. Kuchida, D. Cicale, and P.D. Bass. Preliminary assessment of the Meat Imaging Japan (MIJ) beef grading smart phone application as it compares to a current USDA validated beef grading camera vision system. Reciprocal Meat Conference, Reno, NV.
9. Oliver, K.F., J.B. Van Buren, J.B. Hall, M.L., Heimbuch, J.A. Nasados, P.D. Bass, and M.J. Colle. 2021. Impact of maternal nutrition on postnatal growth and carcass traits of crossbred beef steers. Reciprocal Meat Conference, Reno, NV.

**Kansas – Pendell:**

1. Shear, H.E.a, and **D.L. Pendell**. “Economic Cost of Traceability in U.S. Beef Production.” *Frontiers in Animal Science*. December (2020).
2. Webb, M.J.a, J.J. Block, A.A. Harty, R.R. Salverson, R.F. Daly, J.R. Jaeger, K.R. Underwood, R.N. Funston, **D.L. Pendell**, C.A. Rotz, K.C. Olson, and A.D. Blair. “Cattle and carcass performance, and life cycle assessment of production systems utilizing additive combinations of growth promotant technologies.” *Translational Animal Science.* November (2020)

**Kansas – Chao:**

*Journal Articles*

1. Wu, W.J., Welter, A. A., Olson, B. A., Rice, E. A., O’Quinn, T.G., Houser, T., Boyle,E. A., Magnin-Bissel, G and **Chao, M. D.** (2021). Biochemical factors affecting Asian consumers’ sensory preferences of six beef shank cuts. *Meat and Muscle Biology,* 5(1): 6, 1–18. doi:10.22175/mmb.11626

*Abstracts*

1. Welter, A. A., Koulicoff, L. A., Verrill, E. and **Chao, M. D.** (2021). Native beef MMP-2 may contribute to postmortem collagen degradation in extended aged beef *Proceedings of 67th International Congress of Meat Science and Technology*, Krakow, Poland.
2. Koulicoff, L. A., Chun, C. K. Y., O’Quinn, T.G. and **Chao, M. D.** (2021). Native beef collagenase may contribute to postmortem collagen degradation and alteration of connective tissue texture. *Proceedings of 74th Reciprocal Meats Conference,* Reno, NV.
3. Chun, C. K. Y., Welti, R., Roth, M., Richards, M. and **Chao, M. D.** (2021). Exploring the potential effect of anti-phospholipase A2 antibody to extend beef shelflife in a beef liposome model system. *Proceedings of 74th Reciprocal Meats Conference,* Reno, NV.
4. Velasco-Ayala, C., Hammond, P. A., Chun, C. K. Y., Welter, A. A., O’Quinn, T.G., Boyle, E., Geisbrecht, E. and **Chao, M. D.** (2021). An investigation of the relationship between sarcomere length and meat tenderness and a novel way to measure sarcomere length.*Proceedings of 74th Reciprocal Meats Conference,* Reno, NV.
5. Hammond, P. A., Chun, C. K. Y., Wu, W. J., Welter, A. A., O’Quinn, T.G., Magnin-Bissel, G. and **Chao, M. D.** (2021). An investigation on the influence of various biochemical tenderness factors on eight different bovine muscles. *Proceedings of 74th Reciprocal Meats Conference,* Reno, NV.
6. Verrill, E, Wu, W. J., and **Chao, M. D.** (2021). A proposed ELISA method to evaluate elastin content in beef shank and understanding elastin contents effect on beef shank tenderness. *Proceedings of 74th Reciprocal Meats Conference,* Reno, NV.

**Kansas – Tonsor:**

1. Pudenz, C.C., J.L. Mitchell, L.L. Schulz, and **G.T. Tonsor**. “U.S. Cattle Producer Adoption of Secure Beef Supply Plan Enhanced Biosecurity Practices and Food-and-Mouth Disease Preparedness.” *Frontiers in Veterinary Science*. Forthcoming.
2. Appuhamilage, B.P.M. and **G.T. Tonsor**. “Impact of Weather on Cow-Calf Industry Locations and Production in the United States.” *Agricultural Systems.* Forthcoming.
3. Bina, J.D., T.C. Schroeder, and **G.T. Tonsor**. “Conditional Feeder Cattle Hedge Ratios: Cross Hedging with Fluctuating Corn Prices.” *J of Commodity Markets*.Forthcoming.
4. **Tonsor, G.T**., J.L. Lusk, and S.L. Tonsor. “Meat Demand Monitor during COVID-19.” *Animals*. Special Issue: Data-Driven Decision Making in Animal Industries. Forthcoming. ([LINK](https://www.mdpi.com/2076-2615/11/4/1040))
5. Lusk, J.L. and **G.T. Tonsor**. “Supply and Demand Indices and their Welfare Implications.” *Q Open.* Forthcoming. ([LINK](https://academic.oup.com/qopen/article/1/1/qoaa008/6094642))
6. Appuhamilage, B.P.M. and **G.T. Tonsor**. “Weather Effects on U.S. Cow-Calf Production: A Long-Term Panel Analysis.” *Agribusiness: An International Journal*. Forthcoming. ([LINK](https://onlinelibrary.wiley.com/doi/full/10.1002/agr.21697))
7. Mitchell, J.L., **G.T. Tonsor**, and L.L. Schulz. (2021). “The Market for Traceability with Applications to U.S. Feeder Cattle." *European Review of Agricultural Economics.* 48:447-476. ([LINK](https://academic.oup.com/erae/article/48/3/447/5986602))
8. McKendree, M.G.S., **G.T. Tonsor**, and L.L. Schulz. (2021). “Management of Multiple Sources of Risk in Livestock Production.” *Journal of Agricultural and Applied Economics.* 53:75-93. ([LINK](https://www.cambridge.org/core/journals/journal-of-agricultural-and-applied-economics/article/management-of-multiple-sources-of-risk-in-livestock-production/62D01C72A30AD7F559AF1F52D1BDD1A2))
9. Lusk, J.L., **G.T. Tonsor**, and L.L. Schulz. (2021). “Beef and Pork Marketing Margins and Price Spreads during COVID-19.” *Applied Economic Perspectives and Policy*. 43:4-23. Special Issue Lead Article.

**Nebraska – Calkins and Sullivan:**

*Journal Articles*

1. M.L. Henriott, N.J. Herrera, F.A. Ribeiro, K.B. Hart, N.A. Bland, K. Eskridge, C.R. Calkins. 2020. Impact of myoglobin oxygenation state prior to frozen storage on color stability of thawed beef steaks through retail display. Meat Science

https://doi.org/10.1016/j.meatsci.2020.108232

https://authors.elsevier.com/a/1bS0S16J4lftRH

1. Felipe Azevedo Ribeiro, Soon K. Lau, Sérgio B. Pflanzer, Jeyamkondan Subbiah, Chris R. Calkins. 2020. Color and lipid stability of dry aged beef during retail display. Meat Science https://doi.org/10.1016/j.meatsci.2020.108274

https://authors.elsevier.com/a/1ba-X16J4lftXt

1. Morgan L Henriott, Nicolas J Herrera, Felipe A Ribeiro, Kellen B Hart, Nicolas A Bland, Chris R Calkins. 2020. Impact of myoglobin oxygenation level on color stability of frozen beef steaks. Journal of Animal Science, Volume 98, Issue 7, July 2020, skaa193,

https://doi.org/10.1093/jas/skaa193

1. Nicolas J. Herrera, Nicolas A. Bland, Felipe A. Ribeiro, Morgan L. Henriott, Eric M. Hofferber, Jakob Meier, Jessica L. Petersen, Nicole M. Iverson, Chris R. Calkins. 2021. Oxidative stress and postmortem meat quality in crossbred lambs. Journal of Animal Science, Volume 99, Issue 7, 1-13. 2021, <https://doi.org/10.1093/jas/skab156>
2. Iverson, Nicole, Hofferber, Eric, Meier, Jakob, Herrera, Nicolas, Calkins, Chris, Kachman, Stephen. 2020. Development of a Single Walled Carbon Nanotube Sensor for Long Term Implantation and Detection in a Large Animal Model. November 2020 ECS Meeting Abstracts MA2020-02(67):3413-3413 DOI:10.1149/MA2020-02673413mtgabs
3. Eric Hofferber, Jakob Meier, Nicolas Herrera, Joseph Stapleton, Kayla Ney, Becca Francis, Chris Calkins and Nicole Iverson. 2021. Novel Methods to Extract and Quantify Sensors based on Single Wall Carbon Nanotube Fluorescence from Animal Tissue and Hydrogel-Based Platforms. Methods and Applications in Fluorescence, Volume 9, Number 2 025005 <https://doi.org/10.1088/2050-6120/abea07>
4. Felipe A. Ribeiro, Soon K. Lau, Rebecca A. Furbeck, Nicolas J. Herrera, Morgan L. Henriott, Nicolas A. Bland, Samodha C. Fernando, Jeyamkondan Subbiah, Gary A. Sullivan, and Chris R. Calkins. 2021. Ultimate pH effects on dry-aged beef quality. Meat Science Volume 172, February 2021, 108365 <https://doi.org/10.1016/j.meatsci.2020.108365>
5. Hunt. H.B., Watson. S.C., Chaves, B.D., Cavender, G.A., Sullivan, G.A. 2021. Fate of generic E. coli in nonintact beef steaks during sous vide cooking at different holding time and temperature combinations. In Press: Accepted to Food Protection Trends on 8-3-2021.

## *Other Peer Reviewed Educational Material*

1. Nicolas A. Bland, Nicolas J. Herrera, Felipe A. Ribeiro, Morgan L. Henriott, Kellen B. Hart, Chris R. Calkins. 2021. Proteomic Analysis of Oxidized Proteins in Beef. The Nebraska Beef Cattle Report. vol. MP 110, pp.74 – 80.
2. Nicolas J. Herrera, Felipe A. Ribeiro, Nicolas A. Bland, Morgan L. Henriott, Kellen B. Hart, Jessica L. Petersen, Chris R. Calkins. 2021. The Impact of Oxidative Stress on Postmortem Meat Quality. The Nebraska Beef Cattle Report. vol. MP 110, pp. 82-87.
3. Nicolas J. Herrera, Felipe A. Ribeiro, Nicolas A. Bland, Morgan L. Henriott, Kellen B. Hart, Chris R. Calkins. 2021. The Relationship of Liver Abscess Scores and Early Postmortem Meat Tenderness. The Nebraska Beef Cattle Report. vol. MP 110, pp. 81-82.
4. Joseph A. Sonderman, Soon K. Lau, Felipe A Ribeiro, David M. Velasco, Nicolas A. Bland, Nicolas J. Herrera, Morgan L. Henriott, Jeyamkondan Subbiah, Chris R. Calkins. 2021. Accelerated Dry Aging under Anaerobic Conditions. The Nebraska Beef Cattle Report. vol. MP 110, pp. 88-90.
5. Hunt. H.B., Watson. S.C., Chaves, B.D., Sullivan, G.A.2022Fate of *Salmonella* in beef steaks during sous vide cooking. Nebraska Beef Cattle Report. MP112:104-105. (in press)
6. Hunt. H.B., Watson. S.C., Chaves, B.D., Sullivan, G.A.2021Fate of generic *E. coli* in beef steaks during sous vide cooking at different holding time and temperature combinations. Nebraska Beef Cattle Report. MP110:91-92.
7. Watson, S.C., Furbeck, R.A., Chavez, B.D., Sullivan, G.A.2021. *Pseudomonas* survive thermal processing and grow during vacuum packaged storage in an emulsified beef system. Nebraska Beef Cattle Report. MP110:72-73.

*Abstracts and Conference Proceedings*

1. Watson, S.C., Furbeck, R.A., Chaves, B.D., Fernando, S.C., Sullivan, G.A., 2021. Impact on antimicrobial interventions on spoilage bacteria during extended storage of raw, vacuum packaged beef from two facilities. Reciprocal Meat Conference, Reno, NV. August 15-18.
2. Hunt, H.B., Watson, S.C., Chaves, B.D., Sullivan, G.A., 2021. Fate of Generic Salmonella enterica serotypes Typhimurium, Enteritidis, and Heidelberg in Beef Steaks during Sous Vide Cooking at Different Holding Time and Temperature Combinations. Reciprocal Meat Conference, Reno, NV. August 15-18.
3. Watson, S.C., Furbeck, R.A., Chavez, B.D., Sullivan, G.A. 2020. Spoilage Pseudomonas survive thermal processing and grow during vacuum packaged storage in an emulsified meat system. International Congress of Meat Science and Technology, Virtual, August 3-6, 2020.
4. Hunt, H.B., Watson, S.C., Chavez, B.D., Sullivan, G.A. 2020. Fate of Escherichia coli ATCC 25922 in beef steaks during sous vide cooking at different holding time and temperature combinations. International Congress of Meat Science and Technology, Virtual, August 3-6, 2020.
5. Impact of Diet and Quality Grade on Proteomic Analysis of Oxidized Proteins in Beef.

N. A. Bland, N. J. Herrera, F. A. Ribeiro, M. L. Henriott, K. B. Hart, and C. R. Calkins

Meat and Muscle Biology 2021, 5(2):72

1. Effects of Bone and Subcutaneous Fat on the Yield and Physical-Chemical Traits of Dry Aged Beef. P. S. Bernardo, F. A. Ribeiro, C. R. Calkins, and S. B. Pflanzer

Meat and Muscle Biology 2021, 5(2):73

1. Oxidative Stress as a Measure of Postmortem Meat Quality in Crossbred Lambs.

N. J. Herrera, N. A. Bland, F. A. Ribeiro, M. L. Henriott, J. L. Petersen, and C. R. Calkins. Meat and Muscle Biology 2021, 5(2):90

*Thesis*

1. Velazco, D.M. 2021. Enhancement of Dry-Aged Beef Quality by Dietary Supplementation of High Levels of Vitamin E. M.S. Thesis. University of Nebraska, Lincoln.
2. Sonderman,. J.A. 2021. Low-Oxygen Dry Aging of Beef. M.S. Thesis. University of Nebraska, Lincoln.

**Nevada – De Mello:**

*Refereed 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. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7278849/>
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. <https://www.kosfaj.org/archive/view_article?pid=kosfa-40-3-484>
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. <https://www.sciencedirect.com/science/article/pii/S0309174019308952>
4. Shebs-Maurine, E.S., Torres,E .S., Yeh-Parker, de Mello, A.S. 2020, Application of MS bacteriophages on contaminated trimmings reduces Escherichia coli O157 and non-O157 in ground beef. Meat Science. <https://www.sciencedirect.com/science/article/pii/S0309174020306756?via%3Dihub>

*Abstracts*

1. Shebs, E. L., Giotto, F. M., Laidler, S. T., and de Mello, A. S. 2020. Effects of bacteriophages and peroxyacetic acid applications on beef contaminated with *Salmonella* during different grinding stages. 2020. The 73rd Reciprocal Meat Conference of the American Meat Science Association / 66th International Congress of Meat Science and Technology.
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. The 73rd Reciprocal Meat Conference of the American Meat Science Association / 66th International Congress of Meat Science and Technology.
3. Giotto, F.M., Cavender, A.M., Shebs-Maurine, E.L., Fonseca, M.A., de Mello, A.S. 2020. Effects of feeding brewers grains, maize starch, and Omega 3 fatty acids on growth performance, meat quality attributes, and blood stress indicators of veal. The 73rd Reciprocal Meat Conference of the American Meat Science Association / 66th International Congress of Meat Science and Technology.

*Outreach Media*

1. USMEF Sudamerica: Carcass grading: An essential tool to ensure meat quality. Classificação de Carcaças: Uma ferramenta essencial para garantir a qualidade da carne / Clasificación de Carcasas, una herramienta esencial para garantizar la calidad de la carne.

(Portuguese-BR) <https://www.youtube.com/watch?v=ROmfwj3ZTNQ&t=15s&ab_channel=USMEFSudamerica>

(Spanish subtitles)

<https://www.youtube.com/watch?v=BDxs9qK_jHg&ab_channel=USMEFSudamerica>

1. USMEF Sudamerica: Carcass fabrication and quality attributes. Processamento das carcaças e atributos de qualidade / Procesamiento de las carcasas y atributos de calidad.

(Portuguese-BR) <https://www.youtube.com/watch?v=1TMGJlinOkE&t=196s&ab_channel=USMEFSudamerica>

(Spanish subtitles)

<https://www.youtube.com/watch?v=qlZ77FG71Q4&ab_channel=USMEFSudamerica>

1. USMEF Sudamerica: Effects of dietary treatments and pre-slaughter factors on meat quality. Efeitos da dieta animal e dos fatores pré-abate na qualidade da carne/ Efectos de la dieta animal y los factores previos al sacrificio en la calidad de la carne.

(Portuguese-BR) <https://www.youtube.com/watch?v=WL7N4r7ao1c&t=103s&ab_channel=USMEFSudamerica>

(Spanish subtitles)

<https://www.youtube.com/watch?v=VQhCVsKhRGQ&ab_channel=USMEFSudamerica>

**North Dakota – Maddock:**

1. Fevold M. A. & Grube L. K. & Keller W. L. & Maddock-Carlin K. R. & Maddock R. J., (2021) “Tenderness and Color Stability of Beef Longissimus Thoracis and Semimembranosus Steaks From Carcasses With Varying Hot Carcass Weights”, Meat and Muscle Biology 5(1). p.10, 1 – 7. doi: <https://doi.org/10.22175/mmb.11465>
2. Fevold, M. A., K. R. Maddock-Carlin, and R. J. Maddock. “Various measures of chilling rates for beef carcasses.” Proc 2021 Recip Meats Conference.
3. S. D. Nath, R. Maddock, M. Fevold, W. Keller, and K. Carlin. “The influence of beef carcass weight on troponin-T degradation and heat shock protein 70 in two different models.” Proc 2020 International Congress of Meat Science and Technology.
4. Michaella Fevold, Laura Grube, Wanda Keller, Kasey Maddock-Carlin, Robert Maddock. Tenderness and juiciness of beef steaks from varying hot carcass weights. 2019 NDSU Beef and Sheep Report. Available at: https://www.ag.ndsu.edu/publications/livestock/2019-north-dakota-beef-and-sheep-report

**Indiana – Brad Kim:**

*Peer-review journal articles*

1. Guedes-Oliveira, J.M., Kim, Y.H.B., Conte-Junior, C.A. 2021. What are the potential strategies to achieve healthier meat products? A Review. International Journal of Food Science. <https://doi.org/10.1111/ijfs.15104>.
2. Setyabrata, D., Cooper B.R., Sobreira, T.J.P., Legako, J.F., Martini, S., Kim, Y.H.B.\* 2021. Elucidating mechanisms involved in flavor generation of dry-aged beef loins using metabolomics approach. Food Research International. 139:109969.
3. Xue, S., Setyabrata, D., Kim, Y.H.B.\* 2021. Evaluation of functional and chemical properties of crust from dry-aged beef loins as novel food ingredient. Meat Science. 173: 108403.
4. Tuell, J., Kim, H.W., Guedes-Oliveira, J.M., Seo, J.K., Schoonmaker, J., Kim, Y.H.B.\* 2021. Arginine supplementation may improve color and redox stability of beef loins through delayed onset of mitochondrial-mediated apoptotic processes. Food Chemistry. 128552.
5. Ma, D., Kim, Y.H.B.\* 2020. Proteolytic changes of myofibrillar and small heat shock proteins in different bovine muscles during aging: their relevance to tenderness and water-holding capacity. Meat Science. 163:108090.
6. Xue, S., Wang, C., Bian, G., Kim, Y.H.B., Han, M.\*, Xu, X.\*, Zhou, G. 2020. Application of high-pressure treatment improves the in vitro protein digestibility of gel-based meat product. Food Chemistry. 306:125602.

*Abstracts*

1. Tuell, J., Yu, Q., Kim, Y.H.B.\*. 2020. Impacts of smart tumbling on muscle ultrastructure, proteolysis and quality attributes of fresh beef loins (M. longissimus lumborum). The 73rd Annual Reciprocal Meat Conference, Virtual Meeting.
2. Tuell, J., Kim, Y.H.B.\*. 2020. Smart tumbling improved quality and palatability attributes of fresh beef M. longissimus lumborum and M. semitendinosus. The 73rd Annual Reciprocal Meat Conference, Virtual Meeting.
3. Nondorf, M., Tuell, J., Maskal, J., Johnson, J., Kim, Y.H.B.\*. 2020. Carcass and meat quality traits of market weight gilts exposed to in utero heat stress. The 73rd Annual Reciprocal Meat Conference, Virtual Meeting.
4. Wagner, A., Setyabrata, D., Kim, Y.H.B.\* 2020. Effect of dry-aging on quality attributes of pork loins. The 73rd Annual Reciprocal Meat Conference, Virtual Meeting.
5. Setyabrata, D., Xue, S., Vierck, K., Legako, J., Cooper, B., Sobreira, T., Kim, Y.H.B.\*. 2020. Investigation into mechanisms underpinning dry-aging impacts on beef quality attributes and flavor-related compounds. The 73rd Annual Reciprocal Meat Conference, Virtual Meeting.
6. Zhang, J., Abdelhaseib, M., Kim, Y.H.B.\*. 2020. Effect of early postmortem oxidative stress on mitochondrial redox stability and apoptosis of two porcine muscles. The 73rd Annual Reciprocal Meat Conference, Virtual Meeting.

**Kentucky – Suman, Surendranath**

Manuscript under review:

1. 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. Ractopamine-induced remodeling in the mitochondrial proteome of postmortem longissimus lumborum muscle from feedlot steers. *Livestock Science.* Under review.

**Mississippi – Dinh**

1. Haines, C., Coatney, K. B., Rivera, D., Schilling, W., & Dinh, T. (2021). Effects of chilling duration on USDA Quality Grade of beef carcasses. *Meat and Muscle Biology*. Accepted/In Copyediting.
2. Poss, M., Coatney, K. T., Rivera, D., Dinh, T., Little, R. D., & Maples, J. G. (2021). Marketing Fed Cattle Based on Expectations of the Underlying Carcass Value Dynamics. *Journal of Agricultural and Applied Economics*, 1-26.
3. Dinh, T. T., To, K. V., & Schilling, M. W. (2021). Fatty acid composition of meat animals as flavor precursors. *Meat and Muscle Biology*, 5(1).
4. Bakker, C., Hite, L., Wright, C., Smart, A., Dinh, T., Blair, A., Underwood, K. and Grubbs, J.K. (2021). Impact of feeding cover crop forage containing brassicas to steers during backgrounding on palatability attributes of beef strip steaks. *Foods*, 10(6), p.1250.
5. Dinh, T., Li, S., Chen, J., Zhu, H., & Suman, S. P. (2021). Post-translational modification of myoglobin in post-rigor longissimus lumborum muscle from beef cattle injected with hydrogen peroxide. The 74th Reciprocal Meat Conference of the American Meat Science Association.
6. Penrod, B. M., Fornes, C. R., Rivera, D., Dinh, T. T. N. (2021). Free amino acids in blood plasma of beef cattle under induced oxidative stress by hydrogen peroxide. 2021 ASAS-CSAS-SSASAS Annual Meeting and Trade Show
7. Dahlgren, C., Goodson, H., Sajeev D., Rivera, D., Dinh, T. T. N. (2021) Oxidative stress biomarkers in blood plasma and pre-rigor tissues of beef cattle induced by hydrogen peroxide. 2021 ASAS-CSAS-SSASAS Annual Meeting and Trade Show
8. Fornes, C. R., Penrod, B. M., Rivera, D., Dinh, T. T. N. (2021). Free amino acids in pre- and post-rigor muscles in beef cattle under induced oxidative stress by hydrogen peroxide. 2021 ASAS-CSAS-SSASAS Annual Meeting and Trade Show.
9. Wang, S., To, K. V., Dahlgren, C., Fornes, C., Hessler, H., Zhang, X., Campbell, Y., Buseman, B., Bass, P., Colle, M., Schilling, M. W., Dinh, T. (2021). Free amino acid content in *longissimus* *lumborum* and *semimembranosus* muscles from electrically stimulated beef carcasses. The 74th Reciprocal Meat Conference of the American Meat Science Association.
10. Wang, S., To, K. V., Dahlgren, C., Sajeev, D., Rivera, D., Schilling, M. W., Suman, S., Dinh, T. (2021). Lean color and oxidative stress biomarkers in post-rigor *longissimus* muscle from beef cattle injected with hydrogen peroxide. The 74th Reciprocal Meat Conference of the American Meat Science Association.

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

*Publications*

1. Muhammad, A., **J.M.** **Thompson**, and K. DeLong. “Implications of KORUS on U.S. beef in South Korea.” *International Journal of Trade and Global Markets*. 13(4). 2020.
2. **Thompson, J**., A. Delgado, H. Hasel, and D. Bonilla. “Effects of Drought and Media-Reported Violence on Cattle Fever Tick Incursions.” *Frontiers in Veterinary Sciences*. 7(373). 2020.
3. Menard, R.J., **J.M. Thompson,** B. English, D. Hughes, A. Griffith, S.A. Smith, and K.L. Jensen. “Economic Impacts from On-Farm Highly Pathogenic Avian Influenza Event in Tennessee.” *Review of Regional Studies.* 50(2). 2020.
4. **Thompson, J**.**M**., D.L. Pendell, A.D. Hagerman, and K.K. Johnson. “International Trade Implications of Highly Pathogenic Poultry Disease Events.” *Agricultural and Resource Economics Review*. 49(3). 2020.
5. Kibler, M. and **J. Thompson.** “Price Determinants of Stock-Type Horses Sold at Public Online Auctions.” *Journal of Agricultural and Applied Economics.* 52(4). 2020.
6. Boyer, C., A. Griffith, **J.M. Thompson**, J. Rhinehart, K. Burdine, and K. Laurent. “Cattle Price Influence on Raising versus Purchasing Bred Heifers.” *Journal of Applied Farm Economics.* 3(2). 2020.
7. Maples, J., **J. Thompson**, J. Anderson, and D. Anderson. “Estimating COVID-19 Impacts on the Broiler Industry.” *Applied Economic Perspectives and Policy.* 43(1). 2021.
8. Weersink, A., M. Von Massow, N. Bannon, J. Ifft, J. Maples, K. McEwan, M. McKendree, C. Nicholson, A. Novakovic, A. Rangarajan, T. Richards, B. Rickard, J. Rude, M. Schipanski, G. Schnitkey, L. Schultz, D. Schuurman, K. Schwartzkopf-Genswein, M. Stecphenson, **J. Thompson**, and K. Wood. “COVID-19 and the Agri-Food System in the United States and Canada.” *Agricultural Systems.* 188. 2021.
9. Trejo-Pech, C., and **J.M. Thompson.** “Discounted Cash Flow Valuation of Conventional and Cage-Free Production Investments” *International Food and Agribusiness Management Review*. 24(2). 2021.
10. **Martinez, C**., J. Maples, and J. Benavidez. "Beef cattle markets and covid‐19." *Applied Economic Perspectives and Policy* 43.1 (2021): 304-314.
11. **Martinez, C.**, C.N.Boyer, and K. Burdine. 2021. “Price Determinants for Feeder Cattle in Tennessee.” Journal of Agricultural and Applied Economics. Submitted June, 2021.
12. Smith, K., K.DeLong, A.P. Griffith, C.N. Boyer, **C. Martinez**, S. Schexnayder, and T. Fyxell. 2021. “The Influence of Farm Demographics and Producer Perceptions on Cow-Calf Producer Horn Fly (Diptera: Muscidae) Management Costs in Tennessee and Texas.”Journal of Economic Entomology. Submitted July 2021.
13. Clemmons, B.A., Schneider, L.G., Melchior, E.A., Hales, K.E., Lindholm-Perry, A.K., Freetly, H.C., Wells, J.E., and **Myer, P.R.** 2021. The effects of feeding ferric citrate on methane production, fermentation, and ruminal microbial populations in growing beef steers. Access Microbiology. doi: 10.1099/acmi.0.000180
14. Clemmons, B.A., Henniger, M.T., and **Myer P.R.** 2021. Data of bacterial community dynamics resulting from total rumen content exchange in beef cattle. BMC Research Notes. 14(308). doi: 10.1186/s13104-021-05726-1