**Multistate Research Activity Accomplishments Report**

**Project/Activity Number**: NC1184

**Project/Activity Title**: Molecular Mechanisms Regulating Skeletal Muscle Growth and Differentiation

**Period Covered**: 10/01/2019-9/30/2020

**Date of This Report**: 11/19/19

**Annual Meeting Date(s)**: 10/22-23/2020

**Station Participants**:

Anthony, Tracy ([tracy.anthony@rutgers.edu](mailto:tracy.anthony@rutgers.edu)) – Rutgers University

Awada, Tala ([tawada2@unl.edu](mailto:tawada2@unl.edu)) – University of Nebraska

Burnett, Derris ([ddb362@msstate.edu](mailto:ddb362@msstate.edu)) – Mississippi State University

Dilger, Anna ([adilger2@illinois.edu](mailto:adilger2@illinois.edu)) – University of Illinois

El-Kadi, Samer ([elkadi@vt.edu](mailto:elkadi@vt.edu)) – Virginia Tech University

Fu, Xing ([xfu1@agcenter.lsu.edu](mailto:xfu1@agcenter.lsu.edu)) – Louisiana State University

Geisbrecht, Erika ([geisbrechte@ksu.edu](mailto:geisbrechte@ksu.edu)) – Kansas State University

Gerrard, David ([dgerrard@vt.edu](mailto:dgerrard@vt.edu)) – Virginia Tech

Gonzalez, John ([jgonz@uga.edu](mailto:jgonz@uga.edu)) – University of Georgia

Guo, Wei ([wguo@wisc.edu](mailto:wguo@wisc.edu)) – University of Wisconsin

Harsh, Bailey ([bharsh2@illinois.edu](mailto:bharsh2@illinois.edu)) – University of Illinois

Huang, Yan ([yxh010@uark.edu](mailto:yxh010@uark.edu)) – University of Arkansas

Kuang, Shihuan ([skuang@purdue.edu](mailto:skuang@purdue.edu)) – Purdue University

Matarneh, Sulaiman ([sulaiman.matarneh@usu.edu](mailto:sulaiman.matarneh@usu.edu)) – Utah State University

Reed, Sarah ([sarah.reed@uconn.edu](mailto:sarah.reed@uconn.edu)) – University of Connecticut (host)

Rhoads, Rob ([rhoadsr@vt.edu](mailto:rhoadsr@vt.edu)) – Virginia Tech University

Selsby, Joshua ([jselsby@iastate.edu](mailto:jselsby@iastate.edu)) – Iowa State University

Strasburg, Gale ([stragale@msu.edu](mailto:stragale@msu.edu)) – Michigan State University

Thornton, Kara ([kara.thornton@usu.edu](mailto:kara.thornton@usu.edu)) – Utah State University

Velleman, Sandy ([velleman.1@osu.edu](mailto:velleman.1@osu.edu)) – Ohio State University

White, Sarah ([shwhite@tamu.edu](mailto:shwhite@tamu.edu)) – Texas A&M University

Yates, Dustin ([dustin.yates@unl.edu](mailto:dustin.yates@unl.edu)) – University of Nebraska

Zhou, Huaijun ([hzhou@ucdavis.edu](mailto:hzhou@ucdavis.edu)) – University of California Davis

**Brief Summary of Minutes of Annual Meeting:**

The annual NC1184 technical committee meeting was held virtually on October 22 and 23, 2020. The meeting was hosted by Dr. Sarah Reed of the Department of Animal Science, University of Connecticut. On October 22nd, the group was welcomed by Dr. Reed, who shared information about the area, college, and department. The group then began with oral station reports.

On October 23rd at 10 AM, the group had a conference call with Dr. Mark Mirando, USDA/NIFA, who outlined current funding opportunities, the USDA NIFA budget, statistics on the number of proposals submitted annually and funding rates, and an update on NIFA’s move from Washington, D.C. to Kansas City. Dr. Mirando also introduced Dr. Tim Sullivan and Dr. Bob Smith. A question and answer session followed Dr. Mirando’s update. After the call with Dr. Mirando, the groups continued with station reports.

The group voted to hold the 2022 meeting at the University of Wisconsin, to be hosted by Dr. Wei Guo and the 2023 meeting will be held at Washington State University, to be hosted by Dr. Min Du.

The 2021 meeting will be held at the University of Georgia, hosted by Dr. John Gonzalez.

**Accomplishments:**

**Objective 1: Characterize the signal transduction pathway that regulates skeletal muscle growth and metabolism including the influence of endogenous growth factors and various production practices.**

**Alabama Station:**

1. Determining the effects of dietary inclusion of the vitamin D metabolite, 25-hydroxycholecalciferol in commercial broiler production systems will positively impact the way the poultry industry feeds broiler breeder hens and their offspring to improve feed efficiency and meat yield. Presented an abstract at the 2020 PSA meeting and shared information with stakeholders.

**Connecticut Station:**

1. Bred 46 ewes, fed control, restricted or overfed diets, and have 91 lambs on the ground with LPS challenges, muscle biopsies, and necropsies planned for November 2020-Feb 2021.

**Georgia Station:**

1. Found *in ovo* injection of nicotinamide riboside increased muscle fiber density, but resulted in reduced cyclin D3 expression at hatching.
2. Found commercial pig transport trailer vibrations are great enough to elicit muscle damage if sustained for a long period of time.

**Illinois Station:**

1. To determine the effect of maternal immune activation on offspring muscle and immune system development, pregnant gilts were infected with the porcine reproductive and respiratory syndrome virus (PRRSV) in mid-gestation and fed diets devoid of or enriched with soy isoflavones.
2. Pregnant gilts infected with PRRSV exhibited the expected sickness behavior (febrile response, reduction in feed intake) with few mitigating effects of supplemental isoflavones. Offspring body and muscle weights at birth were not were reduced by maternal PRRSV infection, but at 21d of age, piglets from infected dams had reduced body and muscle weights. This was likely the effect of persistent postnatal PRRSV infection in offspring. Muscle fiber number was not altered by maternal PRRSV infection.
3. Offspring immune response to both an innate and adaptive immune challenge was amplified in piglets from PRRSV infected dams, especially those from dams receiving diets enriched in soy isoflavones.
4. To determine the effect of maternal immune activation on offspring muscle and immune system development, pregnant gilts were infected with the porcine reproductive and respiratory syndrome virus (PRRSV) in mid-gestation and fed diets devoid of or enriched with soy isoflavones.
5. Pregnant gilts infected with PRRSV exhibited the expected sickness behavior (febrile response, reduction in feed intake) with few mitigating effects of supplemental isoflavones. Offspring body and muscle weights at birth were not were reduced by maternal PRRSV infection, but at 21d of age, piglets from infected dams had reduced body and muscle weights. This was likely the effect of persistent postnatal PRRSV infection in offspring. Muscle fiber number was not altered by maternal PRRSV infection.
6. Offspring immune response to both an innate and adaptive immune challenge was amplified in piglets from PRRSV infected dams, especially those from dams receiving diets enriched in soy isoflavones.

**Iowa Station:**

1. In collaboration with Dr. Rhoads (Virginia Tech), we are working to better understand the interaction of heat stress with exposure to the mycotoxin, zearalanone. Our most current data indicate that zearalanone does not augment HS-mediated muscle dysfunction.
2. In conjunction with Dr. Rhoads (Virginia Tech), we have made further inroads into the role of biological sex on the muscular response to heat stress. Our preliminary findings indicate broad muscle dysfunction in muscle from females while muscle from males subjected to similar heating injury appears resistant to this dysfunction. We are eager to probe this idea further using muscle from males and females heated under identical conditions.
3. To better understand lysosomal degradation of autophagosomes we have perfected an approach to isolate a lysosome-enriched fraction.

**Kansas Station:**

1. A NUAK-BAG3-HSC70 complex regulates Filamin protein turnover during muscle development and growth
2. The NUAK serine/threonine kinase regulates serial sarcomere addition, possibly through transcriptional upregulation of translation initiation components
3. Activation of insulin signaling via Akt or S6K can restore muscle mass

**Louisiana Station:**

1. Single cell RNA-seq identified multiple cell types in bovine skeletal muscle tissue including the fibro/adipogenic progenitor (FAP) population which gives rise to both fibroblasts and adipocytes.
2. Multiple FAP subpopulations with distinct gene expression profiles were identified. Some of them expressed higher level of fibrillar collagens while the others expressed higher level of collagens enriched in the basement membrane.
3. Compared to Brahman FAPs, Wagyu FAPs expressed higher levels of several proadipogenic genes, which possibly contributes to the more abundant intramuscular adipocytes in Wagyu.

**Nebraska Station:**

1. Increased our understanding of the mechanisms underlying intrinsic deficits in functional capacity of IUGR fetal myoblasts. Reduced myoblast function and muscle growth was associated with enhanced responsiveness of NFκB-associated inflammatory pathways in addition to altered β adrenergic signaling activity.

**North Carolina Station:**

1. Demonstrated that tilapia derived myotubes metabolize ammonia, which results in a down regulation of myostatin rather than the upregulation of myostatin observed in mammalian muscle.

**South Dakota Station:**

1. Coated and non-coated steroidal implants in finishing heifers. This pooled-analysis investigate the influence of estradiol and trenbolone acetate implants in heifers across varying days on feed. Specific to the interests of this research project, the pooled-analysis evaluated feedlot growth performance, carcass traits, and USDA Yield and Quality grade distribution in a large pen setting at feed yards located at various locations in the U.S.
2. Evaluated the influence of chromium propionate on growth performance, carcass traits and muscle histology parameters in a small pen feedlot setting.
3. Evaluated the influence of body weight and steroidal implant status on growth performance, carcass traits, and pulmonary arterial pressure.

**Utah Station:**

1. Demonstrated that TBA, polyamines and polyamine precursors are all capable of altering differentiation of primary bovine satellite cells.
2. Providing mineral deficient receiving cattle with various levels of mineral at receiving does not impact growth, but does have an impact on liver mineral concentrations.
3. Beef cattle with bos indicus influence respond better to a combined implant than angus influenced cattle.

**Virginia Station:**

1. Satellite cell activation, replication and fusion with existing muscle fibers represent mechanisms by which muscle growth may be augmented. Dietary fat consumption impacts these dynamics *in vitro*, however, are not recapitulated *in vivo* using a muscle damage repair model suggesting physiology is somehow capable of mitigating tissue level cell population dynamics.
2. Wooden breast muscle is an emerging pathology in the breast muscle of fast-growing broilers and has a profound impact on poultry meat quality. The high ultimate pH characteristic of this malady is a result of reduced contractile tissues in the affected area.
3. Understanding the biological factors impinging on the eating quality of beef are important in the demand and variability in meat tenderness and ultimately purchases by consumers. Protein markers associated with energy metabolism and some contractile protein networks appear to be involved in fresh beef quality.
4. Nutritional manipulations aimed at enhancing muscle growth of neonatal animals may are possible interventions that could be used to increase muscle growth. Although leucine supplementation enhances muscle growth in the short-term, its effects on muscle growth are ablated in the long-term. While energy supplementation (fat) had a marginal effect on muscle growth, fat deposition in the liver was significantly increased.
5. Nutritional control of satellite cell activation holds promise as a strategy to increase muscle deposition and repair in livestock including the horse. Tributyrin, a butyrate pro-drug, supplemented to horses causes stimulates satellite cell cycle re-entry and may be an effective exercise-recovery aid. By contrast, supplementation with butyrate caused a shift toward an oxidative metabolism within muscle fibers.

**Objective 2: Characterize the cellular and molecular basis of myogenesis**

**Alabama Station:**

1. Ongoing work is being conducted regarding the in vitro differentiation capacity of muscle satellite cells from affected and unaffected broilers

**California Station:**

1. Analyzed transcriptome data of pectoralis major muscle in broilers that were culled weekly from one week post‐hatching to six weeks post‐hatching (market weight).
2. Performing pathway analyses and working to correlate findings (weight, age, pathology, etc.) reported in the first study with gene expression changes so that we can go back to the muscle tissue to examine progression markers in white striping.

**Hawaii Station:**

1. Myostatin (MSTN) is a negative regulator of skeletal muscle growth and a study was developed to investigate whether active immunization of hens against MSTN produces eggs containing anti-MSTN antibodies, leading to the improvement of skeletal muscle growth of their chicks.
   1. The BW of the MSTN (1312±18.7 g) group was statistically not different from that of the Control (1351±22 g), but the BW of the Myo2 (1237±18.3 g) was significantly lower than that of the Control. Similarly, carcass, breast muscle, and bone-in leg weights of the MSTN were not different from those of the Control, but those of the Myo2 were significantly smaller than those of the Control.
   2. In Western blot analysis, serum and egg yolk IgY showed binding affinity to the recombinant chMSTN but no affinity to a bioactive MSTN, suggesting that the antibodies from the MSTN and Myo2 groups have little affinity to bioactive MSTN.
   3. The lack of affinity to bioactive MSTN of the serum and IgY from the MSTN group appears to explain the lack of difference in muscle mass between the Control and MSTN groups but the cause of reduced muscle mass of the Myo2 group is not clear, thus further studies are required to elucidate the underlying reason.

**Indiana Station:**

1. Used state-of-art single cell RNA sequencing to illustrate cell dynamics and reveal novel subpopulations in regenerating skeletal muscles.
2. Determined the effects of Notch inhibitors in adipocytes differentiation and metabolism in porcine and murine models.

**Kansas Station:**

1. High glycolytic flux is essential to maintain glycolytic enzyme levels (aldoase and phosphoglycerate mutase) to promote cell growth
2. Amino acid supplementation rescues muscle mass resulting from decreased glycolytic intermediates

**Nebraska Station:**

1. Demonstrated that skeletal muscle growth restriction in IUGR-born lambs is improved by clenbuterol when administered daily from birth to 60 days of age. Skeletal muscle glucose metabolism was also improved by clenbuterol treatment in IUGR juvenile lambs.

**New Jersey Station:**

1. The NJ Station revealed for the first time the skeletal muscle metabolome in horses after a bout of exhaustive exercise. More specifically, we described the impact of training and fitness on the post-exercise metabolomic response in the skeletal muscle of Standardbred horses. Key findings:
   1. While sex independently influenced body composition and distance run following training, sex did not affect the skeletal muscle metabolome.
   2. Exercise-induced metabolomic alterations largely centered on the branched-chain amino acids, xenobiotics, and a variety of lipid and nucleotide-related metabolites.
   3. Training increased the relative abundance of almost every identified lipid species in skeletal muscle, and yet acute exercise in the conditioned state decreased the relative abundance of almost all lipid-related species in skeletal muscle by 24 h post-exercise.

**Ohio Station:**

1. Hot temperatures increased rates of proliferation and differentiation of pectoralis major (p. major) muscle satellite cells.
2. Cold temperatures inhibited rates of proliferation and differentiation of p. major muscle satellite cells.
3. If the hot temperature was applied during p. major muscle satellite cell proliferation, it resulted in greater stimulatory effects on differentiation than if the hot temperature was administered only during differentiation. Similarly, cold temperature administered during proliferation tended to have more suppressive effects on differentiation than if the cold temperature was applied only during differentiation.
4. Growth selection has resulted in the p. major muscle satellite cells from the faster-growing commercial turkeys to be more sensitive to hot temperature during both proliferation and differentiation. The increased rates of proliferation and differentiation in vivo may result in a greater potential to accrete more satellite cells to drive myofiber hypertrophy, which could impact post-hatch breast muscle growth and structure.

**South Dakota Station:**

1. Investigated the influence of ractopamine HCL and trenbolone acetate plus estradiol on myogenic mRNA, beta-adrenergic receptors, and blood metabolites.
2. Evaluated the influence of dietary vitamin A requirements in finish steers and the effect on growth performance and carcass traits in a small pen feedlot setting. Future work related to impacts on skeletal muscle fiber type and satellite cell populations is ongoing.
3. Evaluated the influence of zinc propionate on growth performance, carcass traits and muscle histology parameters in a small pen feedlot setting.

**Utah Station:**

1. Found that time of harvest after a stressful event impacted expression of P-HSPβ1, troponin and PARK7, steak color and serum TBARS. Additionally, initial cortisol response impacted protein expression of P-HSPβ1 and serum TBARS.
2. Revealed that mitochondria can significantly contribute to postmortem muscle metabolism, and ultimately, its quality as fresh meat.
3. Showed that mitochondria can modulate muscle postmortem proteolysis and tenderization through buffering cytosolic calcium levels.

**Virginia Station:**

1. Postnatal skeletal muscle growth requires satellite cell activation and fusion with existing myofibers. Delay or absence of satellite cell proliferation and differentiation leads to a reduction in postnatal muscle hypertrophy and reduced growth potential. Calcium and phosphate are necessary for normal muscle development, and deficiencies cause altered satellite cell function and reduced muscle accumulation.
2. Protein diet had a tendency to be interactively influenced by time in which differentiating satellite cells in protein excess pigs at day 0 had higher levels of expression of differentiation promoting miR-1, and protein adequate pigs at day 3 had the lowest expression compared to other diets at each timepoint.

**Objective 3: Characterize mechanism of protein assembly and degradation in skeletal muscle**

**California Station**

1. Tracked white striping, gross muscle pathology, and histological evidence of muscle

pathology. With these findings we have developed linear regression models that show a

positive correlation between white striping, gross pathology, and histopathology relative to weight and age.

**Kansas Station:**

1. The E3 ubiquitin ligase TRIM32 is required for the maintenance of costamere proteins (integrins, sarcoglycans, dystroglycan)
2. Identification of NUAK in the prevention of BAG3-mediated protein aggregation via autophagic lysosomal degradation

**New Jersey Station:**

1. Continue to examine the impact of diet on skeletal muscle protein synthesis using deuterium oxide as a metabolic tracer.
2. Continue to develop ribosomal profiling methods to reveal the skeletal muscle translatome following changes in nutritional status or activity.
3. Using the Ribo-tag mouse to expand on these concepts and also utilize stable isotopes to trace metabolic fate of amino acids beyond use as a substrate for protein biosynthesis. The goal is to better understand the interface between nitrogen metabolism and proteostasis.

**Impact Statements:**

Objective 1:

Changes in knowledge:

1. Information regarding the impacts of various nutrients in production animal species on muscle development and growth characteristics will ultimately improve the efficiency of meat production and sustainability of commercial livestock industries in the USA.
2. Demonstrate that skeletal muscle-specific growth and metabolic deficits in the IUGR fetus persisted in the juvenile animal and thus were the result of stress-induced adaptive fetal programming. In addition, the percentage of body fat (which was not different from controls in IUGR fetuses and IUGR-born neonates) was greater in IUGR-born juvenile lambs than controls, indicating the appearance of catch-up growth after the appearance of metabolic deficits.
3. Demonstrated the effects of coated and non-coated implants, zinc propionate, vitamin A, chromium propionate, and beta agonists on cattle muscle growth.
4. Heat stress continues to negatively impact swine production and will do so at progressively greater magnitudes should environmental models be accurate and/or pigs continue to be selected for protein accretion. Our discovery of a sex effect of heat stress could lead to renewed focus of sexed semen, influence the location of new barn construction, and barrow and gilt management strategies.
5. While increased calorie intake, especially in the form of fat, alters whole body health and well-being, it doesn’t appear to alter the ability of the muscle to regenerate following after an injury.
6. Higher than normal muscle pH values postmortem in breast meat of broiler carcasses is not from global changes in muscle tissue energy metabolism.
7. It may be possible to select cattle on their propensity to produce tender beef if nutrient intake and other management criteria are held constant.
8. While leucine supplementation had no effect on muscle growth, protein deposition in skeletal muscles could be marginally enhanced with energy supplementation, however hepatic fat deposition may present health issues for the animal if used long-term.
9. Tributyrin and butyrate alter skeletal muscle composition and satellite cell dynamics representing a nutritional mechanism for improving repair and metabolism.

Objective 2:

Changes in knowledge:

1. Developed a fundamental understanding of the cell’s intrinsic molecules and extrinsic signals that regulate skeletal muscle development, growth and regeneration.
2. Information regarding the role myogenic stem cells (satellite cells) may play in the development of the costly myopathy known as Wooden Breast currently impacting the commercial broiler chicken industry was presented at key poultry industry stakeholder meetings. This information adds to the body of knowledge surrounding the Wooden Breast condition and will aid the poultry industry in furthering the investigation into the cause and strategies to eliminate this costly meat quality defect from the poultry meat supply.
3. We were able to demonstrate that IUGR skeletal muscle and myoblast deficits were associated with adaptive changes in β adrenergic based on their responsiveness to clenbuterol. These mechanisms represent potential therapeutic targets for improving growth and metabolic outcomes in IUGR-born offspring.
4. Dysregulation of autophagy is emerging as a common cellular dysfunction in a variety of pathological conditions including muscular dystrophy and heat stress. Stimulation of autophagy may provide immediate and profound impacts to the agricultural and biomedical communities.
5. Data indicate that diets deficient in Ca-PO4 decrease satellite cell activity which may lead to a reduction in postnatal muscle growth. Additionally, excess dietary Ca-PO4 appears to reduce satellite cell proliferation and differentiation in vitro. Diets adequate in Ca-PO4 have the greatest proliferation and differentiation rates which may improve the growth potential of the animal.
6. Dietary protein levels in excess of what is currently considered required during the neonatal period allows for improved growth and feed efficiency. Additionally, early dietary protein deficiency slows down muscle growth.

Objective 3:

1. The New Jersey Station developed the necessary methodology to study the transcriptome and translatome in skeletal muscle. Development of RNA sequencing and Ribo-seq in mouse tissues as well as measurement of protein synthesis using deuterium oxide will provide new technical platforms to investigate skeletal muscle protein homeostasis in response to nutrients and activity in collaboration with other NC1184 investigators.

**Collaborative Grants:**

Selsby, Baumgard, Rhoads, and White. USDA/AFRI Foundation Grant, “Calcium regulation as a contributor to heat stress-mediated skeletal muscle dysfunction,” $500,000, 1/1/21-12/31/23.

Selsby, Baumgard, Ross, Schulz, Ramirez, Serao, Rhoads, and White, USDA/AFRI IDEA Grant, “Basic and applied consequences of heat stress in barrows and gilts,” $1,000,000, 9/1/20-8/30/25.

Selsby, Baumgard, and Rhoads. USDA/AFRI Foundation Grant, Administrative supplement (2017-05931), $37,241, 1/1/18-12/31/21.

Strasburg, G., Velleman, S.G., and Reed K. N AFRI, “Influence of Thermal Challenge on Turkey Muscle Development and Meat Quality,” 975,000, 3/2014-2/2019.

Strasburg, G., Velleman, S.G., Reed, K. NIFA AFRI, “Turkey Breast Muscle Development: The Biological Response to Thermal Challenge in Production Birds,” $500,000, 4/1/2020-3/31/23.

**Collaborative Publications:**

Apaoblaza, S.D. Gerrard, S.K. Matarneh, J. Wicks, L. Kirkpatrick, E.M. England, T.L. Scheffler, S.K. Duckett, H. Shi, S. da Luz e Silva, A.L. Grant, D.E. Gerrard. (2019). Muscle from grass- and grain-fed beef differs. Meat Science, 161:107996.

Baldi, G. C-N. Yen, M.R Daughtry, J. Bodmer, B.C. Bowker, H. Zhuang, M. Petracci and D.E. Gerrard. 2020. Exploring the factors contributing to the high ultimate pH of broiler Pectoralis major muscles affected by Wooden Breast condition. Frontiers in Physiology 11:343.

Biggs ME, Kroscher KA, Zhao LD, Zhang Z, Wall EH, Bravo DM, Rhoads RP. 2020. Dietary supplementation of artificial sweetener and capsicum oleoresin as a strategy to mitigate the negative consequences of heat stress on pig performance. J Anim Sci. 98(5):skaa131. doi: 10.1093/jas/skaa131.

Dang, D.S., J.F. Buhler, H.T. Davis, K.J. Thornton, T.L. Scheffler, S.K. Matarneh. (2020). Inhibition of mitochondrial calcium uniporter enhances postmortem proteolysis and tenderness in beef cattle. Meat Science, 162:108039.

Baggerman, J. O., Z. K. Smith, A. J. Thompson, J. Kim, J. E. Hergenreder, W. Rounds, and B. J. Johnson. 2020. Chromium propionate supplementation alters animal growth performance, carcass characteristics, and skeletal muscle properties in feedlot steers. Translational Animal Science 4(3)doi: 10.1093/tas/txaa146

Harris, T., Z. Smith, F. Ribeiro, M. Jennings, G. Vogel, and B. Johnson. 2020. Ractopamine Hydrochloride and Estradiol+ Trenbolone Acetate Implants Alter Myogenic mRNA, β-Adrenergic Receptors, and Blood Metabolites. Open Journal of Animal Sciences 10(03):447.

Horton, K.A., Sporer, K.R.B., Tempelman, R.J., Malilia, Y., Reed, K.M., Velleman, S.G., and Strasburg, G.M. 2020. Knockdown of death-associated protein expression induces global transcriptome changes in proliferating and differentiating muscle satellite cells. Frontiers in Avian Physiology. <https://doi.org/10.3389/fphys.2020.01036>

Matarneh, S.K., C-N. Yen, J. Bodmer, S.W. El-Kadi, A. Grant, D.E. Gerrard. (2021). Mitochondria influence glycolytic and tricarboxylic acid cycle metabolism under postmortem simulating conditions. Meat Science. 172:108316.

Reichhardt, C.C., A. Ahmadpour, R.G. Christensen, N.E. Ineck, G.K. Murdoch, K.J. Thornton. 2021. Understanding the influence of trenbolone acetate and polyamines on proliferation of bovine satellite cells. Domestic Animal Endocrinology. 74. Doi: 10.1016/j.domaniend.2020.106479.

Smith, Z., D. Renter, B. Holland, A. Word, G. Crawford, W. Nichols, B. Nuttelman, M. Streeter, L. Walter, and J. Hutcheson. 2020a. A pooled analysis of six large-pen feedlot studies: Effects of a non-coated initial and terminal implant compared with a single initial and delayed-release implant on arrival in feedlot heifers. Translational Animal Science 4(3):txaa109.

Smith, Z. K., P. T. Anderson, and B. J. Johnson. 2020b. Finishing Cattle in All-Natural and Conventional Production Systems. Open Journal of Animal Sciences 10(02):237.

Smith, Z. K., and B. J. Johnson. 2020. Mechanisms of steroidal implants to improve beef cattle growth: a review. J Appl Anim Res 48(1):133-141. doi: 10.1080/09712119.2020.1751642

Vogel, T. A., J. M. Neary, Z. K. Smith, and B. J. Johnson. 2020. Body Weight and Steroidal Implants Impact Animal Growth Performance, Sera Metabolites, and Pulmonary Arterial Pressure in Feedlot Cattle. Open Journal of Animal Sciences 10(03):414.

Wellmann, K., J. Baggerman, W. Burson, Z. Smith, J. Kim, J. Hergenreder, W. Rounds, B. Bernhard, and B. Johnson. 2020a. Effects of zinc propionate supplementation on performance, skeletal muscle fiber and receptor characteristics in beef steers. J Anim Sci

Wellmann, K. B., J. Kim, P. M. Urso, Z. K. Smith, and B. J. Johnson. 2020b. Evaluation of the dietary vitamin A requirement of finishing steers via systematic depletion and repletion, and its effects on performance and carcass characteristics. J Anim Sci doi: 10.1093/jas/skaa266

Xu, J., Strasburg, G.M., Reed, K.M., and Velleman, S.G. 2020. Response of Turkey Pectoralis Major Muscle Satellite Cells to Hot and Cold Thermal Stress: Effect of Growth Selection on Satellite Cell Proliferation and Differentiation. Comparative Biochemistry and Physiology Pt. A. Accepted pending revisions.

Zhang W, Kroscher KA, Murray RL, Gagliardi R, Guiltinan C, Rhoads RP, Stahl CH. 2020. Dietary Calcium and Phosphorus Amounts Affect Development and Tissue-Specific Stem Cell Characteristics in Neonatal Pigs. J Nutr. 150(5):1086-1092. doi: 10.1093/jn/nxaa011

**Book Chapters: None**

**Abstracts, Posters, and Professional Presentations:**

Anthony, T. 2019. “Dietary Sulfur Amino Acid Restriction and the Integrated Stress Response”, Orentriech Foundation for the Advancement of Science, Cold Spring, NY, Oct 17

Anthony, T. 2020. “Amino Acid Nutrition and the Integrated Stress Response”, University of Arkansas Medical Sciences/Arkansas Children’s Research Center, Jan 10

Anthony, T. 2020. “Amino Acid Nutrition and the Integrated Stress Response”, Department of Kinesiology and Health seminar series, Rutgers University, Jan 15

Anthony, T. 2020. “Branched Chain Amino Acid Deficiency and Neurological Diseases”, New York Academy of Sciences Virtual Conference on Branched Chain Amino Acids and Human Disease, May 14.

Anthony, T. 2020. “Amino Acid Insufficiency and Protein Homeostasis”, FASEB SRC Virtual Conference on Nutrient Sensing and Metabolic Signaling, Aug 11.

Fausnacht, D., Kroscher, K.A., Selsby, J.T., Baumgard, L.H. and Rhoads, R.P. 2020. Heat stress increases respiratory exchange ratio while reducing daily energy expenditure in growing pigs. The FASEB Journal, 34: 1-1. doi:10.1096/fasebj.2020.34.s1.02440Kuang, S. Cell Metabolism Meeting, Chinese Society of Cell Biology, Nanjing, China

Gonzalez, J. M. 2019. Utilizing Nicotinamide Riboside for Agricultural Applications. Invited talk to Kemin.

Gerrard S, Seymour K, Yonke J, El-Kadi SW. Dietary Fatty Acid Composition influences growth performance and hepatic metabolism in neonatal pigs. The FASEB Journal; 34: 1 doi.org/10.1096/fasebj.2020.34.s1.06868

Kroscher, K.A., Fausnacht, D.W., Murray, R.L., Zhang, W., Stahl, C.H. and Rhoads, R.P. 2020. Abundance of miRNA during muscle growth is not influenced by dietary protein inclusion levels in neonatal pigs. The FASEB Journal, 34: 1-1. doi:10.1096/fasebj.2020.34.s1.06006

Kuang, S. Max-Plank Institute Guangdong Laboratory of Regenerative Medicine, Guangzhou, China

Kuang, S. Marshall Institute for Interdisciplinary Research (MIIR), Huntington, WV

Kuang, S. Virtual Seminar, Zhejiang University, Hangzhou, China

Kuang, S. Virtual Seminar, Cincinnati Children’s Hospital, Cincinnati, OH

Okamoto, L.L., C.C. Reichhardt, B.P. Griffin, L.A. Smith, G.K. Murdoch, K.J. Thornton. Examining the effects of estradiol, trenbolone acetate, or polyamines on bovine satellite cell differentiation. American Society for Animal Science Annual Conference, July 2020, held virtually.

Rudolph T, Abeyta M, Rhoads RP, Baumgard LH, and Selsby JT. Sex complicates the effect and treatment of heat stress. Experimental Biology, San Diego, CA, April, 2020.

Yonke J, Seymour K, El-Kadi SW. Leucine supplementation does not enhance translation initiation of low birth‐weight neonatal pigs despite greater Sestrin2 expression in skeletal muscle. FASEB Journal; 34: 1 doi.org/10.1096/fasebj.2020.34.s1.06190

**Theses/Dissertations:**

Kellie Kroscher, “Nutritional Strategies to Improve Pig Growth and Performance”, Ph.D. Dissertation. 2020.

**Other Publications and Presentations:**

Rudolph T, Rhoads R, Baumgard L, and Selsby JT. Why we should sweat heat stress. National Hog Farmer. December, 2019.

https://www.nationalhogfarmer.com/animal-health/why-we-should-sweat-heat-stress