

Meat Science and Muscle Biology: Muscle and Meat Biochemistry

828 ASAS Early Career Award: Proteome basis of muscle- and species-specificity in meat color stability. S. P. Suman*, *University of Kentucky, Lexington.*

At the point-of-sale, meat color is an important quality governing the consumers' purchase decisions. Maintaining consumer-desirable cherry-red color of fresh meat is critical to retailing, and discoloration-induced quality deterioration in fresh meat leads to more than \$1 billion annual revenue loss to the United States livestock industry. The chemistry of myoglobin and its interactions with other biomolecules in post-mortem skeletal muscles are the major factors influencing meat color stability. Characterizing the molecular basis of these interactions is critical to developing novel strategies to improve meat color. High-throughput analytical tools in proteomics offer valuable means to examine the fundamental mechanisms of meat color biochemistry. In this perspective, proteomics has been successfully employed to characterize the molecular basis of muscle- and species-specificity in meat discoloration. Beef muscles in a carcass demonstrate variations in color stability, based on which they are categorized as color-stable and color-labile. Two-dimensional gel electrophoresis and mass spectrometry were employed to characterize the sarcoplasmic proteomes of beef color-stable (*Longissimus lumborum*) and color-labile (*Psoas major*) muscles and to correlate the differential abundance of proteomes to color stability. Proteome analyses identified 16 differentially abundant proteins, including antioxidant proteins and chaperones, in beef muscles. Proteins demonstrating positive correlation with color stability were over-abundant in *Longissimus*. The results suggested that the color stability of beef *Longissimus* could be attributed to the over-abundance of antioxidant proteins and chaperones, which minimizes myoglobin oxidation. Dietary vitamin E improves color and lipid stabilities in beef; however, in pork, while lipid oxidation is minimized by vitamin E supplementation, a color-stabilizing effect is not observed. Mass spectrometric analyses revealed that pork myoglobin is inherently less susceptible to lipid oxidation-induced oxidation than its beef counterpart, due to the differences in the primary structure and the number of nucleophilic histidines. This finding offers an explanation for why dietary vitamin E supplementation has only limited effect on pork color.

Key Words: meat color, longissimus, vitamin E

688 Effects of myogenin on muscle fiber types and muscle oxidative metabolism. L. N. Zhu*, Y. Ren, J. Q. Chen, and Y. Z. Wang, *Institute of Feed Science, Zhejiang University, The Key Laboratory of Molecular Animal Nutrition, Ministry of Education, Zhejiang Provincial Laboratory of Feed and Animal Nutrition, Hangzhou, Zhejiang, China.*

Skeletal muscle fiber type composition is one of the important factors influencing muscle growth and meat quality. As a member of myogenic transcription factors, myogenin (MyoG) is required for embryonic myoblast differentiation, but expression continues in mature muscle tissue of adult animals, especially in oxidative metabolic muscle, suggesting that it may play a more extended role. Therefore, using MyoG gong transfer mice and C2C12 myoblasts as models in vivo and in vitro respectively, we elected to study the role of MyoG on muscle fiber types and oxidative metabolism by using overexpression and siRNA suppression strategies. Overexpression of MyoG by DNA electroporation in mouse gastrocnemius muscle had no significant effect on fiber type composition, but upregulated the mRNA expression ($P < 0.01$)

and enzyme activity ($P < 0.05$) of oxidative succinic dehydrogenase (SDH). In addition, downregulations of glycolytic enzyme lactate dehydrogenase (LDH, $P < 0.05$) and pyruvate dehydrogenase (PK, $P < 0.05$) activities were found in gong transfer mice. In vitro experiments verified the results obtained in mice that stable MyoG transfected differentiating C2C12 cells showed higher mRNA expression levels of myosin heavy chain (MyHC) isoform IIX ($P < 0.01$) and SDH ($P < 0.05$), while the LDH mRNA attenuated. Enzyme activities of SDH ($P < 0.01$) and LDH ($P < 0.05$) were similarly altered as the mRNA levels. When MyoG was knocked-down in C2C12 cells, MyHC IIX expression ($P < 0.05$) was decreased but the mRNA level ($P < 0.05$) and enzyme activity ($P < 0.05$) of SDH were increased. Downregulating MyoG also increased glycolytic enzyme PK ($P < 0.05$) and hexokinase (HK, $P < 0.05$) activities. Based on those results, we concluded that MyoG does not change the major MyHC fiber isoforms (MyHC I / MyHC IIB), but probably influence the shift toward oxidative metabolism in muscle. These results contribute to further understanding the role of MyoG in skeletal muscle energy metabolism, and also help to explore the key genes regulating meat quality.

Key Words: myogenin, muscle fiber type, oxidative metabolism

689 FNDC5 transcript variants and protein detection in skeletal muscle and plasma of cattle. K. Komolka¹, E. Albrecht¹, J. Brenmoehl², A. Hoeflich², and S. Maak*¹, ¹*Institute for Muscle Biology and Growth, Leibniz Institute for Farm Animal Biology, Dummerstorf, Germany,* ²*Institute for Genome Biology, Leibniz Institute for Farm Animal Biology, Dummerstorf, Germany.*

Fibronectin type III domain containing 5 (FNDC5) encodes a type I transmembrane protein located in peroxisomes. Physical activity leads to cleavage and release of a part of this protein. This processed protein, called irisin, induces "browning" of white adipocytes and thermogenesis in mice. Irisin is related to body composition in mice and human and thus, may be a candidate for variation in carcass composition in cattle. Bovine FNDC5 was automatically annotated on chromosome 2 but information on the locus is incomplete and contains errors. We therefore characterized FNDC5 transcripts in bovine skeletal muscle by cDNA sequencing. Two groups of Charolais × Holstein F₂-bulls with different intramuscular fat content (1.9%, n = 10 vs. 6.8%, n = 10; $P < 0.001$) were investigated. Total FNDC5 mRNA abundance, measured with RT-qPCR, was not different between both groups ($P > 0.05$). However, sequence analyses revealed the existence of 3 and 5 alternative exons in the 5'- and 3'-region of the gene, respectively. One transcript was present in muscle samples of all animals in both groups, whereas 2 further variants were more frequently detected in bulls with high IMF. This suggests that total FNDC5 mRNA in skeletal muscle of individual bulls may be composed of different transcripts. All observed transcript variants would result in different length and amino acid composition of the N- and C-terminal regions of the bovine FNDC5 protein, respectively. The irisin domain remained unaffected in all cases. In accordance with the observed transcript variability at this locus, 3 specific bands for FNDC5 protein were detected in bovine skeletal muscle by Western blot. Immuno-histochemical staining of FNDC5 revealed signals at the plasma membrane and in the cytosol of muscle fibers. In bovine plasma, specific bands for a single FNDC5 protein and irisin were detectable. This suggests release of a soluble FNDC5 form and of irisin from skeletal muscle into circulation as described for mice and human. Our results

provide the first experimental data on the FNDC5 locus in a farm animal species and a basis for functional investigations.

Key Words: FNDC5, irisin, cattle

690 Effect of aging on muscle color from Nellore beef cattle.

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This objective of this study was to evaluate the effects of aging on color of 5 muscles: biceps femoris (BF), gluteus medius (GM), longissimus dorsi (LD), Ssemitendinosus (ST) and trapezius thoracis (TT) from young bulls fed in feedlot. Fourteen young bulls (Nellore), with 15 mo of age were confined to individual stalls with feeders and drinkers. The diet was consisted of 40% corn silage and 60% of concentrate. After 60 d of feed, the animals were harvest and the carcasses were chilled at 0°C for 24 h. The muscles were removed, cut into 2.54 cm steaks and individually vacuum packaged and chilled at 0°C for 1, 7 and 14 d post mortem. The color reading was conducted on the surface, using the CIE L*a*b* system, collected using a Minolta on the first posterior steak of each muscle. The experiment was conducted according to a completely randomized design in a factorial arrangement 3 × 5 (3 aging days × 5 muscles) with 14 replicates. Data were analyzed by the GLM procedure of SAS, and the Tukey test used considering 5% probability. The interaction between aging days and muscles was significant ($P = 0.02$) for redness (a*). The lightness (L*) from beef evaluated in 1 d was lower (41.30; $P = 0.01$) than beef evaluated in 7 (42.90) or 14 d (43.33). The beef evaluated in 14 d had greater b* ($P < 0.01$). The ST muscle had greater L* (49.52; $P < 0.01$) compared with the other muscles: BF (39.90), GM (41.19), LD (41.28) and TT (40.63). The ST muscle had lower a* (14.60; $P < 0.01$) than those muscles evaluated: BF (15.70), GM (15.93), LD (15.95) and TT (16.35). The BF muscle had lower b* (13.65; $P < 0.01$) than GM muscle (15.01). The ST muscle had greater value of b* (17.50; $P < 0.01$) than those muscles evaluated. The predominant fiber types within muscles, as white fibers are characterized by less myoglobin and a lighter appearance. Muscles with lower myoglobin content were less color stable because their myoglobin was oxidized at a greater frequency to maintain normal cellular respiration. The aging for 14 d had a greater L*, a* and b* of beef. The ST muscle had lower a*, greater L* and b* than BF, GM, LD, and TT muscles.

Key Words: biceps femoris, lightness, longissimus

691 Comparison of histochemical characteristics and meat quality of longissimus dorsi muscle between commercial pig breeds (Yorkshire × Landrace × Duroc vs. Yorkshire × Berkshire × Duroc crossbred pigs). G. D. Kim¹, K. B. Kwon², E. Y. Jung³, H. W. Seo³, H. J. Lim³, J. Y. Jeong³, H. S. Yang³, and S. T. Joo³, ¹*Division of Animal Biotechnology, College of Applied Life Sciences, Jeju National University, 66 Jejudaehakro, Jeju, South Korea,* ²*Darby Genetics Inc., Anseong, Gyeonggi-do, South Korea,* ³*Department of Animal Science, Institute of Agriculture & Life Science, Gyeongsang National University, Jinju, Gyeongnam, South Korea.*

The traditional 3-way crossbred Yorkshire × Landrace × Duroc (YLD) pigs have been commonly produced in South Korea. Recently, Berkshire breed was introduced for improving the meat quality of 3-way crossbred pigs. Because Berkshire breed is good in muscle fiber characteristics and in meat quality compared with Landrace breed. The objective of this study was to compare the histochemical characteristics and meat quality

of commercial pig breed, YLD to Yorkshire × Berkshire × Duroc (YBD). A total of 27 YLD (female: 16, castrated male: 11) and 30 YBD (female, n = 17; castrated male, n = 13) were selected and their longissimus dorsi muscles were used to investigate the histochemical characteristics including fiber density, fiber type composition and cross-sectional area, and meat quality such as color, cooking loss, drip loss and Warner-Bratzler shear force (WBSF). All traits of histochemical characteristics showed that YBD had higher values in muscle fiber types I and IIA than YLD ($P < 0.05$). However, YLD had higher density, fiber number and fiber area compositions in muscle fiber type IIB than YBD ($P < 0.05$). There were breed × sex interactions of fiber number and area compositions in type IIA ($P < 0.01$) and IIB ($P < 0.05$), respectively. The female of YBD had the highest compositions of type IIA (10.96% of number composition and 7.71% of area composition, respectively), whereas the female of YLD had the highest compositions of type IIB (89.46% of number composition and 93.78% area composition, respectively). In the result of meat quality analysis, lightness (L*), yellowness (b*) and drip loss showed the significances between breeds ($P < 0.05$). YBD had higher L* value than YLD ($P < 0.05$), whereas b* value and drip loss were lower in YBD than in YLD ($P < 0.05$). However, there were no significances in redness, cooking loss and WBSF between breeds ($P > 0.05$). Therefore, Berkshire breed could be used for improving the composition and size of muscle fiber types I and IIA, and meat color and drip loss in 3-way crossbred pig production.

Key Words: meat quality, muscle fiber, pig

692 Effect of vitamin A on early intramuscular adipogenesis: a model for improving marbling in beef. S. M. Harris^{1,2}, J. L. Schneider², C. Trost², A. M. Gibson², C. J. Rogers¹, J. R. Busboom¹, M. V. Dodson¹, J. B. Lamb¹, and M. Du¹, ¹*Washington State University, Pullman,* ²*Brigham Young University-Idaho, Rexburg, ID.*

Marbling is consistently identified as one of the top beef quality problems. Marbling, or intramuscular fat, is vital for the perceived flavor, juiciness, and tenderness in beef. While intramuscular fat in beef can be improved through genetic selection, prenatal and postnatal factors have a profound effect on intramuscular fat development. Vitamin A deficiencies in cattle during late pregnancy and early lactation are not uncommon. While the effect of vitamin A or retinoic acid (RA) on late intramuscular adipogenesis and lipid accumulation has been well characterized, its effect on early adipogenic differentiation has not been characterized in beef cattle. The objective of this study was to evaluate the effect of vitamin A on early adipogenesis. Stromal vascular (SV) cells were obtained from Angus muscle, which were sorted based on their expression of platelet derived growth factor receptor (PDGFR) α . These cells were then exposed to 4 different treatments, with or without RA and with or without adipogenic media. Cells treated with adipogenic media in addition to RA had the greatest proliferation rate ($P < 0.05$), while there were no differences among other treatments. mRNA expression of peroxisome proliferator-activated receptor (PPAR) γ tended to be higher for both treatments containing RA after 2 d of treatment ($P < 0.1$), while treatment with both adipogenic media and RA enhanced Zfp423 mRNA expression ($P < 0.05$). After 6 d of treatment, Zfp423 expression was the greatest when treated with both adipogenic media and RA ($P < 0.05$). Our results suggest that RA has a stimulatory effect on Zfp423 expression and early adipogenic differentiation of cattle SV cells. These data imply that supplementation of vitamin A to pregnant cattle, especially during late gestation and early lactation, may be an effective method to enhance intramuscular adipogenesis and marbling in beef cattle.

Key Words: marbling, Angus, retinoic acid

693 Enzymes activities in the muscle and subcutaneous fat of steers finished at feedlot fed with lipid sources. G. Fiorentini^{1,2}, I. P. C. Carvalho^{1,2}, J. F. Lage^{1,2}, L. G. Rossi¹, Y. T. G. Salcedo^{1,2}, C. S. Ribeiro Junior^{1,2}, and T. T. Berchielli^{1,3}, ¹University of São Paulo State, Jaboticabal, SP, Brazil, ²São Paulo Research Foundation, São Paulo, SP, Brazil, ³National Institute of Science and Technology in Animal Science, Brasília, DF, Brazil.

The objective of the experiment was to evaluate the effect of lipid sources on the activity of enzymes related to the fatty acid metabolism of feedlot steers. Forty-five Nellore steers (BW = 419 ± 11 kg; 15 ± 2 mo) were utilized. The steers were fed on 60% corn silage and 40% concentrate. Five concentrates were formulated: without additional lipid source (WL); with linseed oil (LO); with palm oil (PO); with soybeans (SB) and with a commercial protected fat (PF; Lactoplus). The diets LO and PO contain 4.5% of oil, the SB diet contain 13.8% of soybeans and PF diet contain 5.1% of Lactoplus on DM basis, resulting in diets with 4.2% of additional ether extract. The concentrates were composed of corn and soybean meal and diets were isonitrogenous (16.0% CP). The experiment was set up as a completely randomized design with 5 treatments and 9 replications and lasted 90 d. After slaughter, samples were taken from the longissimus muscle and subcutaneous fat (between the 12th and 13th rib) for evaluation of the activity of the enzymes. The means were compared by the Tukey test at 5%. The action of Δ^9 -desaturase C18 in the longissimus muscle and subcutaneous fat increased in steers fed with the WL diet and decreased in animals fed with PO and PF ($P = 0.001$). Δ^9 -desaturase C16 had a higher activity in the longissimus muscle of steers fed with WL diet (11.2%) than in those fed with PF (7.53%; $P = 0.01$). In addition, Δ^9 -desaturase C16 activity in subcutaneous fat increased in the diet with LO (15.8%) as compared with steers fed PF (11.3%; $P = 0.02$). The greater elongase activity was detected in steers fed with LO and SB (68.0 in the muscle and 70.1 in the fat), as compared with those fed with PO, WL and PF (64.4 in the muscle and 64.3 in the fat; $P = 0.001$). LO decreased atherogenicity indices (0.69 in the muscle and 0.76 in the fat) in relation to PO (0.85 in the muscle and 1.01 in the fat; $P = 0.001$). Diets with LO and WL increase activity of the Δ^9 -desaturase and thus there is a potential to increase the amount of unsaturated fatty acids in the tissues. Also LO provides less atherogenicity indices.

Key Words: meat quality, protected fat, soybean

694 Comparison of real-time ultrasound measurements for body composition traits to carcass and camera data in feedlot steers. A. J. Thompson*, F. R. B. Ribeiro, S. N. Aragon, A. H. Hossford, J. E. Hergenreder, M. A. Jennings, and B. J. Johnson, *Texas Tech University, Lubbock.*

The objective of this study was to compare measurements of real-time ultrasound (RTU), carcass and camera data to determine body composition in feedlot steers ($n = 72$). The RTU, camera and carcass data were collected on 72 crossbred feedlot steers within a 76-h period. Measurements of RTU were taken by a certified ultrasound technician approximately 24 h before slaughter using an Aloka 500-V instrument with a 17-cm 3.5-MHz transducer. Hair was clipped to less than 0.64 cm and

vegetable oil was applied to enhance image quality. The RTU measured traits consisted of 12–13th rib backfat thickness (uBF, mean = 1.04 cm), 12–13th LM area (uREA, mean = 102.7 cm²), and marbling score (uMARB, mean = 4.6). Intramuscular fat was converted to uMARB by using the equation: uMARB = ((769.7 + (56.69 × uIMF))/100) – 5. Overall means for 48 h chill carcass data were 12–13th rib backfat thickness (cBF, 0.97 cm), 12–13th LM area (cREA, 103.5 cm²), and marbling score (cMARB, 5.0). Marbling scores were converted to a numeric cMARB (Slight⁰⁰ = 4, Small⁰⁰ = 5, and Modest⁰⁰ = 6). Carcass camera data consisted of 12–13th rib backfat thickness (camBF, 0.99 cm), 12–13th LM area (camREA, 103.8 cm²), and marbling score (camMARB, 4.5). Data were analyzed using the PROC REG, MEANS and CORR procedures of SAS. Results show that all 3 methods were highly correlated to each other. Correlations ranged from 0.79 to 0.82, 0.68 to 0.95 and 0.57 to 0.87 for BF, REA, and MARB, respectively. The largest differences between the means (bias) across all 3 methods were 0.07 cm, 0.78 cm² and 0.48 for BF, REA and MARB. Carcass BF and camBF were over predicted by RTU (0.07 and 0.06 cm, respectively), however, REA was under predicted by RTU when compared with cREA and camREA (–0.78 and –1.13 cm², respectively). Camera MARB was over predicted by uMARB (0.17) and cMARB was under predicted (–0.32). These results show that linear measurements of carcass traits can be more accurately predicted when compared with a non-linear measurement (MARB). The results also show that RTU can be used to accurately predict carcass traits immediately before slaughter.

Key Words: ultrasound, carcass, camera

695 Influence of graded levels of Tetracin on physico-chemical properties of broiler meat. A. O. Akinwumi*, A. A. Odunsi, A. B. Omojola, and T. O. Akande, *Ladoke Akintola University of Technology, Ogbomoso, Oyo, Nigeria.*

Veterinary antibiotic Tetracin was administered in feed to broilers at varying levels to study its effect on physical and chemical qualities of poultry meat. Tetracin was administered at 0, 50, 100, 150, and 200 mg/kg of feed for broilers for a period of 6 wk while withdrawal period of 2 weeks was observed as recommended by the manufacturer before slaughter to make an 8-week feeding trial. Breast meat was analyzed for physico-chemical properties. Cooking and thermal losses were expressed as percentage changes in weight and length during cooking respectively, while water-holding capacity (WHC) was determined by the filter press method. Warner-Brazter shear force (WBSF) determination was performed on broiler meat for shear force determination. The results showed that cooking loss, thermal loss and crude protein increased ($P < 0.05$) while WHC and ether extract decreased ($P < 0.05$) with increase in the inclusion level of Tetracin. However, drip loss, chilling loss, shear force, ash and moisture contents of broiler meat showed no significant ($P > 0.05$) differences across the treatment groups. Conclusively, the inclusion of Tetracin improved the chemical properties of broiler meat but the physical properties (cooking loss and WHC) were compromised especially when administered above 100 mg/kg of feed.

Key Words: Tetracin, physical and chemical properties, broiler