National Program 101 Food Animal Production
National Program Annual Report: FY 2008

Introduction

The food animal production national program is charged with conducting cutting edge research to contribute to increased efficiency and sustainability of production of beef and dairy cattle, poultry, swine, and sheep. Research efforts in the animal sciences over the past century have had dramatic impacts on animal agriculture both in terms of improved biological and economic efficiency of production and in terms of quantity, quality, and safety of animal products. Many major challenges remain, however, requiring the dedicated focus of long-term research teams, particularly in the areas of reproductive longevity and animal well-being, adaptability to production environments, product quality, reduction of feed and energy inputs, enhancements in nutrient retention, and reduction of negative environmental impacts.

During 2008, 110 full-time scientists working at 20 locations across the U.S. were actively engaged in 33 research projects in the program. Research projects in this program area were approved through the ARS Office of Scientific Quality Review in 2007, making this the first year of implementation of these five-year project efforts.

Total funding in the program for fiscal year 2008 was approximately $46 M.

Several new permanent scientists were welcomed to the program including:

James Klotz, Research Animal Scientist, Forage-Animal Production Research Unit, Lexington, Kentucky

Lea Rempel, Research Physiologist, Meat and Animal Research Center, Clay Center, Nebraska

Amanda Lindholm-Perry, Research Geneticist, Meat and Animal Research Center, Clay Center, Nebraska

Retiring from the ranks of scientists in the national program during Fiscal Year 2008 was John N. Stellflug, from U.S. Sheep Experiment Station, Dubois, Idaho. William Dozier, III, from the Mid South Area Poultry Research Unit, along with Gary Snowden, Mark Allen, and Justin Holl, from Clay Center, Nebraska, have left to work outside the Agency. The distinguished record of service of these gentlemen in the areas of animal breeding, genetics, and physiology is recognized world-wide in the beef, swine, and sheep industries and they will be missed.

Ronnie Green served as the national program leader for the program until his departure in April 2008. Jeff Silverstein assumed these responsibilities. Contributions to the national program were also provided by program team members Evert Byington and Cyril Gay.

Several scientists in the national program were recognized with prominent awards:

Joe Ford, Clay Center, Nebraska, received American Society for Animal Science Fellow

Tim Smith, Clay Center, Nebraska, received ARS Northern Plains Area Outstanding Scientist Award

John Nienaber, Animal Improvement Research Laboratory, Beltsville, Maryland, for Outstanding Contributions to Nebraska Agriculture, Nebraska Section, American Society of Agricultural and Biological Engineers (ASABE)

William Dozier III, Mid South Area Poultry Research Unit received the SE Federal Laboratory Consortium Technology Award

Robert H. Miller, Animal Improvement Research Laboratory, Beltsville, Maryland, **American Registry Of Professional Animal Scientists** (ARPAS) Chapter Distinguished Service in the Animal Science Award

The high quality and impact of research conducted in the program was further evidenced by the fact that scientists published over 200 referred journal publications and three book chapters, and delivered 120 invited presentations at international and national symposia during the past year. This activity was accompanied by over 40 articles in trade journals and popular press. During the year, 13 new CRADA and MTAs were established and two new patents were filed to researchers in the program.

Administrator's Postdoctoral Awards were granted to:

Sherrill Echternkamp at US MARC, Clay Center, Nebraska, for "Establishment of Maternal Versus Embryonic Genomic Regulation of Early Embryonic development in Cattle and Identification of Genetic Markers Linked to Oocyte and Embryo Quality"

Heng Wei Cheng at the Livestock Behavior Research Unit, West Lafayette, Indiana, for "Modification of Serotonergic System for Controlling Feather Pecking and Cannibalism in Chickens".

Partnerships with land grant and 1890s universities continued to be very important to the success of the national program in 2008. These partnerships are greatly appreciated and take on a

variety of forms including work with those in the states of Arkansas, Colorado, Connecticut, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New York, Oklahoma, Oregon, South Carolina, Texas, Virginia, West Virginia, and Wisconsin.

The following section of the report summarizes high impact research results addressing the various components of the recently implemented national program action plan FY 2008 to 2012.

1) **New Protocol Improves Fertility of Frozen-thawed Boar Semen.** Use of cryopreserved semen in swine has been hampered by the poor performance of frozen-thawed semen which results in farrowing rates of 55% and 8 piglets/litter, which is 20-30 percentage lower and 2-3 fewer pigs per litter than expected with non-frozen semen. In order to obtain better fertility with cryopreserved boar semen, we developed a new protocol where females' time of ovulation was manipulated, and a single insemination of thawed boar semen was timed to have fertile sperm at the site of fertilization 0-4 hours before the expected time of ovulation. With our protocol litter size was about 96% of that using non-frozen semen; while the farrowing rate (80%) was equal to that using nonfrozen semen in conjunction with standard industry breeding procedures. These results show that, with proper treatment of recipient females, frozen-thawed boar semen can be used by swine producers to obtain fertility that is almost as good as non-frozen semen. (National Program 101, Performance Measure 2.2.2)

2) **Genomic predictions of genetic merit for dairy cattle.** Genotypes derived from DNA of 5,285 Holstein bulls and 75 Holstein cows were used in estimating genetic effects for nearly 40,000 single-nucleotide polymorphisms. Based on those effects, genomic predictions for yield (milk, fat, and protein), somatic cell score (indicator for mastitis resistance), productive life (longevity), daughter pregnancy rate (cow fertility), calving ease, final score (conformation), and net merit (a genetic-economic index) were developed. Two different evaluations were developed to predict the genetic merit of an animal's daughters and sons separately. Genomic predictions for genotyped bulls and cows (mostly calves) were distributed in April and July 2008 to owners and to organizations. (National Program 101, Performance Measure 2.2.2)

   Dechow, C.D., Norman, H.D., Zwald, N.R., Cowan, C.M., Meland, O.M. 2008. Relationship between individual herd-heritability estimates and sire misidentification rate. Journal of Dairy Science. 91(4):1640-1647.

   Dechow, C.D., Norman, H.D., Pelensky, C.A. 2008. Short Communication: Variance estimates among herds stratified by individual herd heritability. Journal of Dairy Science. 91(4):1648-1651.

   Kuhn, M.T., Hutchison, J.L. 2008. Prediction of dairy bull fertility from field data: Use of multiple services and identification and utilization of factors affecting bull fertility. Journal of Dairy Science. 91(6):2481-2492.

   Kuhn, M.T., Hutchison, J.L., Norman, H.D. 2008. Modeling Nuisance Variables for

Prediction of Service Sire Fertility. Journal of Dairy Science. 91(7):2823-2835.

Powell, R.L., Sanders, A.H., Norman, H.D. 2008. Investigation of country bias in international genetic evaluations using full-brother information. Journal of Dairy Science. 91(7):2885-2892.

3) **Whole genome SNP assay development for estimating genetic merit.** A research consortium led by the Animal Improvement Programs Laboratory (ARS-BARC), and including US Meat Animal Research Center (ARS-NPA), University of Missouri, Illumina, Inc., National Association of Animal Breeders (a trade group representing cattle artificial insemination organizations in N.A.), INRA (France), and Merial, Inc. developed, tested, and commercialized a genome-wide bovine single nucleotide polymorphism (SNP) beadchip that assays the allele content at approximately 58,000 genome locations. Genotypes for over 10,000 cattle were generated on this SNP chip. Some of these genotypes were used to develop a whole genome selection (WGS) algorithm that produced genome enhanced predictions of genetic merit for three major dairy breeds. Over 3,000 genomic DNA samples were extracted from semen to support this work. The initial success of WGS to enhance selection in Holsteins led to release of unofficial genome enhanced genetic predictions in April 2008. Genome enhanced evaluations are now provided quarterly to the NAAB. (National Program 101, Performance Measure 2.2.2)

   Van Tassell, C.P., Smith, T.P., Matukumalli, L.K., Taylor, J.F., Schnabel, R.D., Lawley, C.T., Haudenschild, C., Moore, S.S., Warren, W.C., Sonstegard, T.S. 2008. SNP discovery and allele frequency estimation by deep sequencing of reduced representation libraries. Nature Methods. 5:247-252.

   Snelling, W.M., Chiu, R., Schein, J.E., Hobbs, M., Abbey, C.A., Adelson, D.L., Aerts, J., Bennett, G.L., Bosdet, I.E., Boussaha, M., Brauning, R., Caetano, A.R., Costa, M.M., Crawford, A.M., Dalrymple, B.P., Eggen, A., Everts-Van Der Wind, A., Floriot, S., Gautier, M., Gill, C.A., Green, R.D., Holt, R., Jann, O., Jones, S.J., Kappes, S.M., Keele, J.W., De Jong, P.J., Larkin, D.M., Lewin, H.A., Mcewan, J.C., Mckay, S., Marra, M.A., Mathewson, C.A., Matukumalli, L.K., Moore, S.S., Murdoch, B., Nicholas, F.W., Osoegawa, K., Roy, A., Salih, H., Schibler, L., Schnabel, R.D., Silveri, L., Skow, L.C., Smith, T.P., Sonstegard, T.S., Taylor, J.F., Tellam, R., Van Tassell, C.P., Williams, J.L., Womack, J.E., Wye, N.H., Yang, G., Zhao, S. 2007. A physical map of the bovine genome. Genome Biology. 8:R165 (17 pp).

4) **Improved housing for cows.** The benefits of installing rubber flooring for cows were examined. Cows were assigned to free-stall housing with either rubber or concrete at the feed-face immediately after their first calving, and managed on this system during all subsequent lactations. Blood variables were investigated, leukocyte counts, phagocytic ability, and neutrophil and monocyte differentiation were examined. The ability of cows on rubber flooring to activate neutrophils and monocytes is indicative of an improved

immune response. These data show the potential benefits of investing in rubber flooring. (National Program 101, Performance Measure 2.2.2)

5) **RNA interference to inhibit viral disease in chickens.** Modern vaccines have reduced productivity loss to viral diseases, however, many viral diseases continue to decrease animal productivity and welfare. Additional tools to complement vaccine control methods could aid in further reducing the negative effects of viral disease. Recently, a system known as RNA interference or RNAi has been developed that reduces the expression of specific genes. Scientists at the Avian Disease Oncology Laboratory in Michigan have adapted this technology to reduce the severity of viral infections in chickens by targeting virus genes. The feasibility of this approach was shown in live birds where Marek's disease virus replication and pathogenesis has been reduced. This method has the potential to inhibit any infectious disease and may offer a valuable tool to control disease. (National Program 101, Performance Measure 2.2.2)

   Chen, M., Granger, A.J., VanBrocklin, M.W., Payne, W.S., Hunt, H.D., Zhang, H.M., Dodgson, J.B., Holmen, S.L. 2007. Inhibition of avian leukosis virus replication by vector-based RNA interference. Virology. 365:464-472.

   Chen, M., Payne, W.S., Hunt, H.D., Zhang, H., Holmen, S.L., Dodgson, J.B. 2008. Inhibition of Marek's disease virus replication by retroviral vector-based RNA interference. Virology. 377:265-272

6) **Accuracy of real-time ultrasound of live sheep for estimating carcass measures, yield, and value.** Real-time ultrasound of live sheep can be used to estimate carcass compositional traits and produce information that can then be used to make sheep breeding decisions, with the goal of improving carcass merit and quality of lamb muscle foods. Research to validate ultrasound as a predictive tool, using current ultrasound technologies and with diverse populations of U.S. sheep, was conducted. Scientists of the U.S. Sheep Experiment Station, Dubois, Idaho, found that real-time ultrasound of live sheep can provide reliable estimates of carcass measures and value, and there are biologic and economic incentives for increasing longissimus muscle area in market lambs. Ultrasound technicians can use the information to validate their procedures, and sheep producers can use the information to make sheep breeding decisions that will improve the value and marketability of their lambs. (National Program 101, Performance Measure 2.2.2)

7) **Identifying genetic mechanisms associated with improved feed efficiency in cattle.** Because feed efficiency is a time consuming and expensive trait to measure, genetic markers of feed efficiency in cattle could greatly enhance selection for this trait. A study was completed in growing steers to identify changes in liver gene expression associated with increased feed conversion efficiency during feed restriction and compensatory weight gain. Several pathways were up regulated during improved feed efficiency included electron transporter activity in the mitochondria. Mitochondrial complex genes will be targets of further characterization because these genes have been associated with increased feed efficiency in poultry and cattle, and with quantitative trait loci for feed

efficiency in cattle. These results will lead to definition of markers to improve selection for feed efficiency in cattle. (National Program 101, Performance Measure 2.2.2).

8) **Value of amino nitrogen sources in ruminant nutrition.** The ability of most ruminal bacteria to use ammonia as a nitrogen source for growth is a highly advantageous characteristic of ruminal fermentation, but non-fiber carbohydrate (NFC) degrading bacteria typically grow faster and more efficiently if amino nitrogen sources (ruminally degraded protein, peptide or amino acids) are also available. ARS Scientists at the Holley Center for Agriculture and Health in Ithaca, NY showed the potential impacts of amino nitrogen on the efficiency of NFC bacterial growth include: 1) carbon sparing and an increased availability of carbohydrate to generate energy, 2) an increase in growth rate and a concomitant decrease in the fraction of energy used to maintain the cells, and 3) a decrease in energy loses (energy spilling). The effect of amino nitrogen sources on bacteria was incorporated into a model of ruminal fermentation that will improve the prediction accuracy of nutrient availability. (National Program 101, Performance Measure 2.2.2).

9) **Diet and management impacts on nutrient losses from dairy farms.** Two integrated feed-manure management trials and a survey of dairy feed practices were conducted to examine relationships between dairy diets, milk production, manure nutrient excretions and environmental risks. On Wisconsin dairy farms, approximately 20-35% of feed crude protein and phosphorus is secreted into milk and the remaining is excreted in manure. The amount and form of nitrogen and phosphorus losses to the environment were highly influenced by what was fed to dairy cows, and other management practices. For example, feeding dietary protein above recommended levels increased excretions of nitrogen in manure, and subsequent ammonia nitrogen loss from barns and field after manure land application. Unnecessary dietary phosphorus supplements dramatically increased total and water-soluble phosphorus concentrations in manure, and runoff from soil surfaces after manure application. Recommendations to use total mixed rations, balancing rations at least four times per year, and milking thrice daily results in highest milk yields and highest levels of feed nitrogen and phosphorus transformed into milk. Dietary options and practices are available that satisfy the nutritional requirements of high-producing dairy cows, and also produce manure less susceptible to environmental loss. (National Program 101, Performance Measure 2.2.2).

10) **Determining germplasm collection requirements for chickens.** Knowing the quantity of germplasm necessary to reconstitute a population is one requirement for genebanks to use in setting goals for germplasm collections. FAO has recommended that to secure a chicken breed, at 150% of reconstitution needs, genebanks have 2,454 straws (0.5 ml) of semen. In FY2007 scientists at the National Animal Germplasm Program in Fort Collins evaluated inseminating hens intramagnally vs intravaginally and found the intramagnal procedure was significantly better. Additionally, econometric procedures were used to evaluate the maximum efficiency and duration by which fertile eggs could be obtained from a single insemination. These results showed that maximum efficiency occurred at day 8 and fertile eggs could be harvested until day 17. These findings significantly impact the development of germplasm collections for chickens. By using intramagnal

insemination, rather than intravaginal insemination the number of units of germplasm required to secure a breed can be reduced from 2,454 to 386. The impact of this finding is that collections of germplasm from chicken breeds can be secured more rapidly at a lower cost of collection and a lower storage cost. (National Program 101, Performance Measure 2.2.2).

11) **Fatty acid composition in beef.** The fat content and composition of beef has received considerable interest in view of its implications for human health and meat quality characteristics. While unsaturated fats are beneficial when consumed in moderation, high levels of saturated fat are associated with increased serum low-density lipoprotein cholesterol concentrations and pose a risk factor for coronary heart disease. In addition, beef with the most desirable flavor has a higher percentage of monounsaturated fatty acids. Scientists at the Range and Livestock Research Center in Miles City, Montana have discovered a QTL with large effects on the fatty acid composition of beef and preliminary results suggest the myostatin locus may be causative. The results guide future research to provide a clearer understanding of genetic mechanisms controlling palatability and healthfulness of beef and should ultimately lead to tools for producing beef of greater value to consumers. (National Program 101, Performance Measure 2.2.2).

Alexander, L.J., Macneil, M.D., Geary, T.W., Snelling, W.M., Rule, D.C., Scanga, J.A. 2007. Quantitative trait loci with additive effect on palatability and fatty acid composition of meat in a Wagyu-Limousin F*2 population. Animal Genetics 38:506-513.

Tshipuliso, N., Alexander, L.J., Geary, T.W., Snelling, W.M., Rule, D.C., Koltes, J.E., Mote, B.E., MacNeil, M.D. 2008. Mapping quantitative trait loci for fatty acid composition that segregate between Wagyu and Limousin. South African Journal of Science 38(2):126-130.

12) **Across-Breed EPD Adjustment Factors**. Beef cattle breed associations produce expected progeny differences (EPD) as a measure of the genetic merit of individual bulls and cows for several economically relevant traits. However, these EPD are not directly comparable among different breeds. To address this problem, across-breed EPD adjustment factors were calculated on 16 breeds for growth traits (birth, weaning, and yearling weights and maternal milk) and on 8 breeds for carcass traits (ribeye area, backfat depth, and marbling) using data from the USMARC Germplasm Evaluation program and EPD from breed associations. These adjustment factors were presented and released at the Beef Improvement Federation meeting to a North American audience, followed by publication on various websites and in the popular press. This research allows producers to more effectively use available genetic resources and thereby more rapidly improve production of lean beef and meat quality. (National Program 101, Performance Measure 2.2.2).

13) **Identification and validation of SNPs in pig calpastatin that are predictive of pork tenderness.** The quality and palatability of fresh retail pork is variable and tenderness is a key factor guiding consumer choices for pork. The ability to selectively breed for

animals that are superior and consistent for meat quality traits would improve consumer acceptance and benefit the pork industry. A quantitative trait locus (QTL) region has been identified for pork tenderness around the calpastatin gene. Three markers in the calpastatin gene were highly significantly associated with slice shear force, a measure of tenderness, in Duroc-Landrace and Duroc-Landrace-Large White populations. These results provide publicly available genetic markers associated with slice shear force that may be useful to the swine industry for marker assisted selection of animals with superior tenderness. (National Program 101, Performance Measure 2.2.2).

14) **Progress mapping the porcine genome.** The swine linkage map is based on over 3400 markers, developed primarily by scientist at the US Meat Animal Research Center in Clay Center, Nebraska. The Swine Genome Sequencing Consortium assembled 172 large fragments, from over 260,000 pieces, covering approximately 98% of the pig genome into a BAC physical map. Several computational methods were utilized to create thousands of links between the linkage and physical maps. Furthermore, comparing the porcine physical map to the human genome, the continuity and local ordering of segments of the porcine genome were improved. Some pig chromosomes are well mapped with few gaps remaining, while others consist of many fragments. The map is publicly accessible on the internet (http://pre.ensembl.org/Sus_scrofa/index.html). This physical map is providing a framework for the generation and assembly of the pig genome sequence. Furthermore, the map is immediately useful to the pig research community to direct maker development, identify genes and fine map quantitative trait loci. (National Program 101, Performance Measure 2.2.2).

Humphary, S.J., Scott, C.E., Clark, R., Marron, B., Bender, C., Camm, N., Davis, J., Jenks, A., Noon, A., Patel, M., Sehra, H., Yang, F., Rogatcheva, M.B., Milan, D., Chardon, P., Rohrer, G.A., Nonneman, D.J., De Jong, P., Meyers, S.N., Archibald, A., Beever, J.E., Schook, L.B., Rogers, J. 2007. A high utility integrated map of the pig genome. Genome Biology. 8:R139.

Alexander, L.J., Juneja, B., Shiroma, D., Nonneman, D.J., Snelling, W.M., Fahrenkrug, S.C. 2007. Comparative and physical mapping of 112 previously reported and 105 new porcine microsatellites. Animal Genetics 38:584-594.

15) **Construction of a Gene Atlas for cattle.** Genome research in cattle was hampered by the lack of data on the expression of genes in normal tissues. Scientists at the US Meat Animal Research Center collected in-depth data on gene expression of 95 normal cattle tissues using “next generation” sequencing technology, and created an interactive database permitting a genome-level view of expression across tissues, tissue types, and tissue functions (e.g., immune tissues, neurological tissues, etc). The bovine Gene Atlas will have substantial impact in research of cattle physiology, genetics, and genomics by providing a control for gene expression patterns to contrast against expression in various physiological states or genetic backgrounds, after it is made available on the web (in progress), and will facilitate annotation of the unfinished bovine genome sequence. (National Program 101, Performance Measure 1.2.3)

16) **Cows with higher calf production potential.** Increased embryo and fetal mortality resulting from crowding in the uterus can be associated with greater than twin pregnancies. Research conducted at the U.S. Meat Animal Research Center found that selecting for increased ovulation rate can be used to increase the number of calves within a pregnancy thus increasing the annual production potential of a cow. However, capacity of the uterus to successfully support the growth of more than two calves may be limiting suggesting the need to include uterine capacity in a selection index for increased birth rate. These findings demonstrate that selection for increased birth rate in beef cattle can be used as a tool for developing cattle with higher production potential. (National Program 101, Performance Measure 2.2.2)

Echternkamp, S.E., Cushman, R.A., Allan, M.F., Thallman, R.M., Gregory, K.E. 2007. Effects of ovulation rate and fetal number on fertility in twin-producing cattle. Journal of Animal Science. 85(12):3228-3238.

Echternkamp, S.E., Thallman, R.M., Cushman, R.A., Allan, M.F., Gregory, K.E. 2007. Increased calf production in cattle selected for twin ovulations. Journal of Animal Science. 85(12):3239-3248.

17) **Evaluation of the effects of early versus normal weaning in beef cattle.** A collaborative study with scientists from the Livestock Issues Research Unit in Lubbock, Texas, and the University of Florida-IFAS, Range Cattle Research and Education Center, Ona, Florida, was conducted to evaluate the effect of early weaning beef calves at 90 days of age compared to normal weaning at 250 days of age. Previous research indicated that early weaning prior to shipment can reduce transportation stress and can increase subsequent performance in the feedlot. These data suggest that coincident weaning and transport stresses may compromise the immune system of calves, thus hindering subsequent performance and health. This study was conducted to determine if the innate immune response of early weaned calves differed from normal weaned calves in response to an immune challenge. Eighteen Brahman x Angus calves were fitted with an indwelling jugular catheters and blood samples for 10 hours to determine serum concentrations of stress hormones, pro-inflammatory cytokines and acute phase proteins. Based upon these data, the innate immune system of early weaned calves appears to be less naïve than that of normal weaned calves, therefore making them more effective at recognizing and eliminating endotoxin from their body. These data suggest that an altered innate immune system may be responsible for the improved feedlot performance previously reported in early weaned calves. (National Program 101, Performance Measure 2.2.2)

Whitlock, B.K., Daniel, J.A., Wilborn, R.R., Elsasser, T.H., Carroll, J.A., Sartin, J.L. 2008. Comparative aspects of the endotoxin- and cytokine-induced endocrine cascade influencing neuroendocrine control of growth and reproduction in farm mammals. Reproduction of Domestic Animals. 43(Suppl. 2):317-323.

18) **Hemodynamics in the caudal artery of beef heifers fed different ergot alkaloid concentrations.** Fescue toxicosis, induced by consumption of ergot alkaloids (e.g.,

ergovaline) produced in endophyte-infected tall fescue, is a syndrome that costs cattle, horse, and small ruminant producers nearly a billion dollars a year in lost production. Although the syndrome was identified approximately 30 years ago, the lack of sensitive tools for measuring in vivo (real time) effects of the intoxication have hindered definition of the threshold level of exposure for induction of fescue toxicosis and also, the development of fully successful mitigation protocols for the syndrome. Recently, scientists at the Forage Animal Production Research Unit in Lexington, Kentucky have validated the use of Doppler ultrasonography for tracking fescue toxicosis induced vascular dysfunction (a primary functional deficit in intoxicated animals) in cattle on endophyte-infected tall fescue. Caudal artery area and blood flow rates were reduced in heifers receiving endophyte-infected tall fescue seed and these reductions were related to dose and length of exposure. These data demonstrate the usefulness of Doppler ultrasound technology as a tool for the real time study of fescue toxicosis and form the beginnings of a database that will be useful in determining the threshold level of intoxication. (National Program 101, Performance Measure 2.2.2)

Aiken, G.E., Kirch, B.H., Strickland, J.R., Bush, L.P., Looper, M.L., Schrick, N.F. 2007. Hemodynamic Responses of the Caudal Artery to Toxic Tall Fescue in Beef Heifers. Journal of Animal Science. 2007. 85:2337-2345.