National Program 101 Food Animal Production

National Program Annual Report: FY2016

NP 101 Mission Statement:

The mission of NP 101 is to foster an abundant, safe, nutritionally wholesome, and competitively priced supply of animal products produced in a viable, competitive, and sustainable animal agriculture sector of the U.S. economy by:

1. Safeguarding and utilizing animal genetic resources, associated genetic and genomic databases, and bioinformatic tools;

2. Developing a basic understanding of food animal physiology for food animal industry priority issues related to animal production, animal well-being, and product quality and healthfulness; and

3. Developing information, best management practices, novel and innovative tools, and technologies that improve animal production systems, enhance human health, and ensure domestic food security.

Introduction

Food animals convert plant materials into animal products that are more nutrient dense and desirable. In addition, food animals convert forages grown on marginal lands that are unsuitable for human consumption into human food products. The nutrient density of food animal products fill a vital role in the diets of people around the world as valuable sources of high quality protein, fatty acids, vitamins and minerals. Dramatic improvements in production efficiencies developed by ARS scientists help ensure international food security and directly impact human health and by reducing the real cost of nutritionally valuable animal products, making animal products more available to those populations most in need. Food animal wastes, when managed properly, contribute to returning nutrients to the soil for further production. Ongoing improvements in food animal nutrition and other production efficiencies reduce grain requirements and manure production, and science based animal waste management strategies provide for the beneficial return of animal waste nutrients to the environment. These improvements reduce microbial contamination and greenhouse gas emissions from livestock and ensure that livestock production remains environmentally sustainable.

During FY 2016, 87 full-time scientists working at 13 locations across the United States were actively engaged in more than 130 independent research projects in the program. Twenty eight appropriated research projects in NP 101 were approved through the ARS Office of Scientific Quality Review in 2012, making this the fourth year of implementation of these five-year project efforts. The fiscal year 2016 appropriated funding for NP101 was $49 million; total funding was $54 million including extramural awards. Twelve new inventions were disclosed

and 2 patents awarded. Additional technology transfer included 12 Material Transfer Agreements and 9 Material Transfer Research Agreements.

In 2016 NP 101 scientists participated in research collaborations with scientists in: Australia, Austria, Belgium, Brazil, Canada, China, Denmark, England, Finland, France, Germany, Israel, Italy, Japan, Malawi, Mexico, Mongolia, Netherlands Antilles, Nigeria, Northern Ireland, Norway, Poland, Republic Of Ireland, Russia, Scotland, South Africa, Spain, Sweden, Switzerland, Taiwan, Turkey, Uganda, and United Kingdom.

Personnel Changes in NP 101

Dr. Caird Rexroad III was acting National Program Leader for Food Animal Production for most of 2016. Dr. Jeffrey Vallet became National Program Leader in September 2016.

New scientists in NP 101:

Benjamin Rosen, Beltsville, Maryland, joined the Animal Genomics and Improvement Laboratory as a Computational Research Biologist.

Paul Broadway, Lubbock, Texas, joined the Livestock Issues Research Unit as a Research Scientist.

Brittney Keel, Clay Center, Nebraska, joined the Reproduction Research Unit as a Research Biologist.

The following scientists retired from the ranks in NP 101:

George Wiggans, Animal Genomics and Improvement Laboratory, Beltsville, Maryland.

William T. Golde, Plum Island Animal Disease Center, Greenport, New York.

The distinguished record of service of these scientists is recognized world-wide and they will be missed in NP101.

The following scientists in NP 101 received prominent awards in 2015:

James Klotz, Lexington, Kentucky, received a Merit Award from the American Forage and Grassland Council for his research accomplishments.

Paul Van Raden, Beltsville, Maryland, received an award for the most cited paper in Breeding Genetics by the Journal of Dairy Science.

Curt Van Tassell, Beltsville, Maryland, was named a Fellow of the American Dairy Science Association.

Tommy Wheeler, Clay Center, Nebraska, was named one of 25 icons of the industry in the last 25 years by National Provisioner magazine.

Major Accomplishments in 2016

This section summarizes significant research results for 2016 that addressed specific components and anticipated products of the FY2013 – 2018 action plan for the Food Animal Production National Program. Within each section, selected accomplishments of individual research projects in NP101 are presented. These accomplishments are highlighted here due to their significance and alignment to action plan components and anticipated products. They are a subset of accomplishments within the program. To see all the accomplishments for each project within the program, please visit

https://www.ars.usda.gov/research/project-list-by-program/?npCode=101&filter=yes&projectStatus=A&projectType=D&filterLocation=&showAllProjects=N&sortBy=L&submitFilter=Filter

Click on each project of interest, then click on the full annual report for each project for the year of interest. Many of the projects are the result of significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA - ARS research and allow scientists to tackle larger problems than can be addressed without such collaborations. Improved food animal production efficiencies decrease the real cost of animal products, making the products more available to people worldwide, and decreasing the environmental footprint of animal production.

Accomplishments are listed below that correspond to each of the Components and Problem Statements of the 2013 – 2018 National Program Action Plan. Preceding each accomplishment, the corresponding anticipated product from the NP101 Action plan is indicated.

Component 1: Improving Production and Production Efficiencies and Enhancing Animal Well-Being and Adaptation in Diverse Food Animal Production Systems

Problem Statement 1A: Improving the Efficiency of Growth and Nutrient Utilization

> **Anticipated Product: Comprehensive characterization of gut microflora in livestock species, including organisms present and their prevalence, and identification of those species that are correlated with improved nutrient efficiency.**

Rumen microbial community changes milk production efficiency. The efficiency of conversion of feed to milk (production efficiency) is a major factor affecting how the U.S. dairy industry impacts the environment, economics, and food supply of the country. Dairy cows vary in milk production efficiency, but only part of the variation among cows is explained by cow genetics. Dairy cows also have different communities of microbes in their rumens. In an effort to determine how these differences affect production efficiency, ARS researchers at Madison, Wisconsin, and collaborators performed near-total exchange of rumen contents between high-

and low-efficiency cows, and showed that these exchanges respectively decreased or increased milk production efficiency of each cow for about 7 days before returning to their previous levels; additionally, after the rumen digesta exchange, the species composition of the rumen bacterial community gradually returned to a composition similar to the original unique profile of each host cow. The results directly implicated the rumen bacterial community as determinants of milk production efficiency. Improvement of milk production efficiency with its concomitant decrease in environmental impact and improvement in farm return over feed costs may be possible if the factors controlling the rumen microbial community can be optimized.

Anticipated Product: Strategies that alter metabolic pathways to improve growth performance and nutrient utilization efficiency in livestock.

Biochanin A, a phytoestrogen produced by red clover, reduces ammonia production in the rumen and improves fiber digestion. Feeding high quality protein to ruminants to improve growth efficiency is limited in utility because of the degradation of protein and rumen microorganisms, which also increases ammonia release into the environment. Biochanin A, a molecule found naturally in red clover, inhibits hyper-ammonia producing bacteria that degrade protein and adversely affect amino acid profiles entering the small intestines. A grazing experiment with pastures of mixed cool-season grasses by ARS in Lexington, Kentucky, demonstrated that adding biochanin A to a dried distillers grain protein supplement significantly increased average daily gain over the pasture-only control treatment. Additionally, Biochanin A inhibition of hyper-ammonia producing bacteria increased cellulolytic bacteria to potentially increase ruminal degradation of fiber. Biochanin A produced by red clover benefits animal performance by improving the quality of digested protein and digestion of dietary fiber. Reducing the excretion of ammonia reduces the impact on the environment.

Anticipated Product: Strategies that alter metabolic pathways to improve growth performance and nutrient utilization efficiency in livestock.

Research confirms environmental value of altering forages for improved nitrogen use efficiency. The chemical composition of forages consumed by dairy cattle affects feed intake and milk production, as well as manure composition and impact on the environment. ARS researchers in Madison, Wisconsin, determined that feeding polyphenolic-containing forages (e.g. birdsfoot trefoil; red clover) and tannin extracts to lactating cows enhanced the efficiency of feed nitrogen use by the cow and reduced the excretion of urea in urine, which in turn reduced production of greenhouse gases on dairy farms. Improvements in the efficiency of feed and reduced urinary nitrogen loss due to feeding forage polyphenols and tannins can reduce feed cost and the environmental impacts of milk production.

Anticipated product: Best management practices and genetic parameters that improve the rate of improvement for growth and feed efficiency for producers.

Beef cattle breeds differ in feed efficiency. Feed cost represents one of the highest variable input costs in beef cattle production systems. Selection of animals that are able to grow faster or eat less feed or both (i.e., increased feed efficiency) could substantially reduce producer costs. In addition to selection, utilization of breeds with high feed efficiency could increase profit prior to

selection strategies. ARS researchers, using data from the germplasm evaluation program in Clay Center, Nebraska, were able to derive differences in heifer and steer feed intake and gain for 18 different beef cattle breeds. Feed efficiency differences among breeds will help producers make breeding decisions to improve feed efficiency in commercial cattle production.

Anticipated product: Biological markers that are useful in predicting and improving growth performance and nutrient utilization efficiency of livestock.

Identification of a key metabolic change in pigs that reduces growth rate. Slow growing pigs result in an estimated $90 million dollar loss to the swine industry each year. The metabolic factors responsible for poor postnatal growth rate in some normal birth weight pigs is not understood. ARS scientists at Beltsville, Maryland analyzed the metabolic activity of the livers from low growth rate pigs which demonstrated no changes in carbohydrate or normal fat metabolism. However, the expression of genes associated with an unusual form of fat metabolism, lipid peroxidation, was increased in livers of slow growing pigs. This is significant because peroxidation results in damage to cells that reduces their growth and development, processes critical for growth in the young pig. This research identifies a key change in metabolism in the slow growing pig that will permit development of nutritional and nutraceutical intervention to promote improvement in growth and wellbeing of these pigs.

Problem Statement 1B: Reducing Reproductive Losses

Anticipated Product: Strategies based on physiological data and biological markers for increasing longevity and lifetime productivity of breeding females in livestock systems.

Glucosamine supplementation during late gestation increases litter size without reducing birth weights or preweaning survival. Previous studies indicated that glucosamine supplementation beneficially altered placental development, but subsequent studies on commercial sows indicated that 10 grams glucosamine per day had equivocal effects on litter size. ARS researchers at Clay Center, Nebraska, in collaboration with an industry partner demonstrated that supplementation of sow gestation diets with 20 grams (.7 ounces) per day glucosamine during the last third of pregnancy resulted in an increase in litter size of over 1 piglet per litter born alive without reducing average birth weights or preweaning survival. Routine supplementation of sow diets with glucosamine would contribute to improved reproductive efficiency in sow herds and improved profitability of swine production.

Anticipated product: Identification of critical control points limiting improvements in reproductive rate in food animals including physiological and management factors.

A hormone receptor that controls testicular function in boars. Fertility of boars has an important impact on reproductive efficiency of swine herds. Most swine producers in the United States mate sows using artificial insemination, requiring an estimated 30 million doses of semen every year. There is a critical need to understand testicular function to develop methods to improve semen production and quality. ARS researchers at Clay Center, Nebraska, in

collaboration with researchers from the University of Nebraska found that boars have a hormone receptor called gonadotropin-releasing hormone receptor 2 (GnRHR2) that is found in special cells types within the testicle. When the receptor was activated, testosterone was increased, which is a steroid important for sperm production. These results indicate a role for GnRHR2 in testosterone production and testicular function in boars. Understanding this role will lead to strategies to improve boar fertility.

Anticipated product: Identification of critical control points limiting improvements in reproductive rate in food animals including physiological and management factors.

Estrus related fertility in estrous synchronized beef cattle is mediated by uterine acidity. Cows that demonstrate behavioral estrus during an ovulation-induction (synchronization) protocol have greater fertility than cows that do not demonstrate behavioral estrus during this time. One mechanism by which this might happen is decreases in uterine pH to improve sperm survival. To test this, ARS researchers at Clay Center, Nebraska, and researchers at South Dakota State University measured sodium/hydrogen transporter gene expression (controls intrauterine pH) and uterine pH in the hours prior to artificial insemination to examine their relationship to behavioral estrus and fertility. In cows that demonstrated behavioral estrus, sodium/hydrogen transporter abundance decreased, whereas there was no change in abundance in cows that did not demonstrate estrus. Decreased uterine pH was associated with increased conception to artificial insemination. Understanding mechanisms controlling the uterine environment during insemination will lead to strategies to improve fertility.

Problem Statement 1C: Enhancing Animal Well-Being and Reducing Stress

Anticipated Product: Species-specific, cost-effective strategies to mitigate animal stress and improve animal well-being and longevity in conventional production systems

Identifying novel antimicrobials to target Clostridium perfringens, a poultry pathogen. Clostridium perfringens is a major disease causing bacterial pathogen in poultry, a source of food poisoning and gas gangrene in humans, and can cause mild to severe disease in pigs. Lessons from Europe suggest that the coming ban on the use of antibiotic growth promotants in animal feed will result in increased incidence of diseases associated with Clostridium, so alternative strategies are needed against this pathogen. An ARS scientist at Beltsville, Maryland, has examined the genomes of 43 Clostridium perfringens isolates from chicken, and identified bacteriophage (viruses that infect bacteria) genomes embedded in the genomes of the bacteria. Hundreds of genes for putative phage enzymes that disrupt bacterial cells were identified using molecular biological tools. Four of these enzymes were tested and shown to kill all 43 of the Clostridium perfringens isolates in lab assays but did not have a deleterious effect on other Gram positive or Gram negative species tested. This is an important step toward identifying novel replacements for antibiotic growth promotants that can be added to poultry feed.

Anticipated Product: Species-specific, cost-effective strategies to mitigate animal stress and improve animal well-being and longevity in conventional production systems

Management options for lambs and meat-goat kids on pastures in the United States. In the United States, lamb and meat goat production is growing rapidly to supply animals for many ethnic markets. However, internal parasite control is a significant management challenge for producers. ARS scientists at El Reno, Oklahoma, along with colleagues at West Virginia University, Michigan State University, and Virginia Tech, finished lambs and meat goats on grass-clover pastures with and without whole cottonseed supplement. Supplemented lambs and meat-goat kids had improved weight gains and better tolerance to internal parasites. Combining cottonseed supplementation with an internal parasite-resistant breed of lamb (Katahdin) and a selective deworming program of individual animals resulted in the least number of dewormer doses given to animals. This information can be used to reduce reliance on dewormers for more sustainable production of lamb and meat goats for niche markets in the United States.

Component 2: Genetic Improvement - Understanding, Improving, and Effectively Using Animal Genetic and Genomic Resources

Problem Statement 2A: Develop bioinformatic and quantitative genomic capacity and infrastructure for research in genomics and metagenomics.

Anticipated Product: Improved annotation of genome sequence assemblies for food animals.

Public release of an improved goat genome assembly. Genome studies in livestock species have made significant advances in eliminating deleterious mutations and in improving production traits that are difficult or expensive to measure. These studies were made possible by the reference livestock genome sequence assemblies that were made at great expense in the preceding decade, but further improvements increase the utility of the genome sequences. ARS scientists in Beltsville, Maryland, and Clay Center Nebraska, working in tandem with members of the National Human Genome Research Institute (NGHRI), BioNano Genomics, Phase Genomics and the PirBright Institute (based in the United Kingdom) have used the latest long-read sequencing technology available at Clay Center to create and release an improved reference genome assembly of the domestic goat. The assembly is >250 times better in contiguity (a key measure of quality and utility), compared to the previous public reference genome. The improved reference genome is supporting advances in genome analysis and identification of biomarkers.

Problem Statement 2B: Identify Functional Genomic Pathways and Their Interactions.

None

Problem Statement 2C: Preserve and Curate Food Animal Genetic Resources.

Anticipated Product: High-quality, comprehensive characterization, evaluation, and Genbank curatorial data made readily accessible, either from a transformed, upgraded,

well-maintained GRIN, from databases housed at GRIN as the primary site, or at sites linked to GRIN.

Introduction of a genomics component for Animal-GRIN (Germplasm Resources Information Network) Version 2 information system. Prior to the development of the genomics component of the Animal-GRIN information system, the livestock research community did not have any mechanism to permanently store genotypes derived from publically funded livestock genomics work. As a result the long-term security of expensive data was at risk and it was difficult for other researchers to access and leverage this information in other experiments. An ARS led team developed a genomics component which is part of Animal-GRIN Version 2. With this component it is possible for public sector researchers to enter their genomic data into the database and the community at large to have access to those genotypes. The developed component also makes possible, for the first time, the linkage and access to genomic, phenotypic, management, and environmental information with a physical tissue sample from the individual animal. This approach serves to protect the public investment in genomic research and affords a broad range of users with the opportunity to leverage previous investments made in genotyping.

Problem Statement 2D: Develop and Implement Genome-Enabled Genetic Improvement Programs.

Anticipated Product: Genetic prediction tools for traits in food animals related to health, production efficiencies, adaptability, and functionality in varied domestic and international production systems.

Identification of markers associated with susceptibility to liver abscesses. Liver abscesses are found at processing in approximately 13% of cattle being fed high energy density rations, as this diet makes them more susceptible to infection from ruminant bacteria that generate acid conditions in the digestive tract. The acidosis and associated liver abscesses seldom result in outward clinical signs but reduce carcass weight and quality, and create an economic impact of -$20 to -$80 per affected animal. The prevalence of abscesses will likely increase as the use of antibiotics for growth promotion is decreased, and because they are not outwardly detectable there is a need for alternate management practices to prevent them. ARS researchers at Clay Center, Nebraska, identified 35 genetic markers associated with abscess susceptibility. These genetic markers may be useful in genetic selection programs to reduce the incidence of disease.

Discovery of genomic locations controlling number of milk glands in swine. Litter size in commercial swine populations has increased steadily for the past decade; however, the number of milk glands in the udder of sows has increased at a slower pace. Number of milk gland in pigs is a heritable trait and has become economically important due to this imbalance. ARS scientists at Clay Center, Nebraska, conducted a genome-wide association study for genes affecting number of milk glands in their commercial swine population. Thirty-three genomic regions were discovered to affect the number of milk glands and these regions explained 39% of the genetic variation present in a validation population that was more similar to contemporary commercial sows. Genetic markers within these regions will enable the swine industry to

increase teat numbers in commercial populations reducing the need for cross-fostering and artificial rearing, which will improve piglet survival.

Anticipated Product: Breeding system designs that optimize integration of genomics and traditional genetic prediction tools in domestic and international production systems.

Expanded national genomic evaluation service for dairy cattle. Control of the dairy cattle national database and responsibility for routine delivery of genetic evaluations was transferred from ARS in Beltsville, Maryland, to the Council on Dairy Cattle Breeding. A copy of the CDCB database is maintained at ARS to allow expanded research on genetic evaluation development and methodology, and CDCB employees interact with ARS on a daily basis. The arrangement allows CDCB to continue expanding data collection and services to the dairy industry while ARS staff focus on research. Projects completed jointly by ARS and CDCB include exchange of Holstein bull genotypes with Switzerland (March 2016) and Japan (May 2016), genomic prediction of breed composition (June 2016), and expansion of genomic evaluations to Guernseys as a fifth dairy cattle breed (April 2016) in cooperation with the United Kingdom and the Isle of Guernsey. The collaboration between ARS and the dairy industry has resulted in a world-leading genomic prediction system and a vast database that producers in about 50 countries now use routinely to accelerate genetic progress and select parents that produce healthier, more productive dairy cattle.

Problem Statement 2E: Improved Techniques for Genetic Modification and Genetic Engineering of Food Animals.

None

Component 3: Measuring and Enhancing Product Quality and Enhancing the Healthfulness of Meat Animal Products

Problem Statement 3A: Systems to Improve Product Quality and Reduce Variation in Meat Animal Products.

Anticipated Product: Development of cost effective technologies to better predict and evaluate meat quality attributes on farm and during processing. Validated methodologies and instrumentation for on-line commercial industry use to determine product quality and yield.

On-line prediction of pork loin quality with the model VQG pork loin grading camera. The National Pork Board is considering development of a pork grading system. Grading cameras can accurately assess meat quality more consistently, thus reducing inherent variation in human subjective evaluation. ARS scientists at Clay Center, Nebraska, in collaboration with Texas Tech University, determined that loin color, marbling, water-holding capacity, and tenderness could be predicted with on-line assessment of loins with the model VQG pork loin grading camera. Implementation of this tool will allow the industry to identify higher quality pork that could be marketed in a premium program.

Problem Statement 3B: Improving the Healthfulness and Nutritional Value of Meat Products from Traditional and Non-Traditional Production Systems.

None

NP101 Projects contributing accomplishments to this report:

PROJECT NO.	PROJECT TITLE	CITY	STATE
3012-31000-005-00D	National Animal Germplasm Program	FORT COLLINS	CO
3040-31000-090-00D	Genetic Research to Enhance Efficient and Sustainable Production of Beef Cattle and Sheep	CLAY CENTER	NE
3040-31000-091-00D	Improving Sow Lifetime Productivity in Swine	CLAY CENTER	NE
3040-31000-093-00D	Strategies to Improve Heifer Selection and Heifer Development	CLAY CENTER	NE
3040-31000-094-00D	Genetic and Genomic Approaches to Improve Swine Reproductive Efficiency	CLAY CENTER	NE
3040-31320-012-00D	Genomic and Metagenomic Approaches to Enhance Efficient and Sustainable Production of Beef Cattle	CLAY CENTER	NE
3040-31430-005-00D	Strategies to Optimize Meat Quality and Composition of Red Meat Animals	CLAY CENTER	NE
3070-31630-006-00D	Improving the Efficiency and Sustainability of Diversified Forage-Based Livestock Production Systems	EL RENO	OK
5042-32630-002-00D	Optimizing the Biology of the Animal-Plant Interface for Improved Sustainability of Forage-Based Animal Enterprises	LEXINGTON	KY
5090-31000-023-00D	Forage Characteristics that Alter Feed Utilization, Manure Characteristics and Environmental Impacts of Dairy Production	MADISON	WI
5090-31000-024-00D	Determining Influence of Microbial, Feed, and Animal Factors on Efficiency of Nutrient Utilization and Performance in Lactating Dairy Cows	MADISON	WI
8042-31000-101-00D	Improving Genetic Predictions in Dairy Animals Using Phenotypic and Genomic Information	BELTSVILLE	MD
8042-31000-103-00D	Developing Genetic Biotechnologies for Increased Food Animal Production, Including Novel Antimicrobials for Improved Health and Product Safety	BELTSVILLE	MD
8042-31000-104-00D	Enhancing Genetic Merit of Ruminants through Genome Selection and Analysis	BELTSVILLE	MD
8042-31630-001-00D	Identification of Biomarkers for Pre and Post Weaning Growth in Swine	BELTSVILLE	MD