FY 2023 Annual Report
USDA-ARS Animal Production and Protection
National Program 101
Food Animal Production

Photo Credit: US Meat Animal Research Center cattle in a pasture

Contents

2023 Overview

USDA-ARS research is organized into four National Program Areas. The mission of the Animal Production and Protection (APP) National Programs is to improve the health, well-being, and efficiency of livestock, poultry, and aquatic food animals to ensure a productive and safe food supply. Within APP, the Food Animal Production National Program (NP101) includes 92 scientists leading 29 congressionally appropriated ($63.8M base funds in FY23) research projects at 16 U.S. locations. Research is conducted in primary food animal species (beef and dairy cattle, swine, sheep, goats, and poultry) addressing research priorities identified by stakeholders. Efforts support animal industry goals of efficient and economically sustainable production of safe, high quality, and affordable food produced using the highest standards for animal welfare, environmental quality, and ecosystems/community services. This annual report summarizes key areas of research accomplishment and contributions of NP101 programs within USDA-ARS for FY 2023.

NP101 Mission

Conduct research to improve food animal production efficiency, industry sustainability, animal welfare, product quality, and nutritional value while safeguarding animal genetic resources.

NP101 Vision

The vision for NP101 is that ARS will provide the scientific community and food animal industries with scientific information, biotechnologies, and best management practices ensuring consumers an abundant supply of competitively priced, high quality animal products that enhance human health, while ensuring domestic food security and enhancing the efficiency, competitiveness, and environmental sustainability of the food animal industry.

NP101 Alignment

NP101 supports the USDA Strategic Plan Goal 3, *Foster and Equitable and Competitive Marketplace for All Agricultural Producers*, and Goal 4, *Provide All Americans Safe, Nutritious Food*. NP101 supports Objective 4.1*, Increase Food Security through Assistance and Access to Nutritious and Affordable Food*.

NP101 aligns with the USDA Science and Research Strategy Priority 1, *Accelerating Innovative Technologies and Practices*; Priority 3, *Bolstering Nutrition Security and Health*; and Priority 4, *Cultivating Resilient Ecosystems*.

NP101 supports Theme 1, *Sustainable Ag Intensification*, from the USDA Science Blueprint 2020 to 2025.

Background

Food animal production contributes to the U.S. rural economy through farm-gate cash receipts and the sales and transactions associated with allied industries, such as animal feeds, farm supplies, germplasm provision and sales, and sales related to animal health products. In 2022, the USDA Economic Research Service (ERS) reported that U.S. animal and animal products were valued at $258.5B in total U.S. commodity cash farm receipts. These U.S. animal and animal products represent 48.3 percent of total U.S. agricultural commodities (ERS, Cash receipts by State (usda.gov), accessed 12/11/2023). Contributions by commodity include: Cattle and Calves

($86.1B), Dairy Products and Milk ($57.2B), Broilers ($50.5B), Hogs ($30.8B), Eggs ($19.3B), Turkey ($7.1B), and all other animals and products ($6.6B).

Animal production is a value-added part of agriculture, converting plant materials into animal products that are sources of high biological value protein and nutrients, like vitamin B12, essential for human health. Ruminant animals (cattle, sheep, goats) convert forages (e.g., grasses, legumes) that are not suitable for human consumption into nutritious human food products, using lands that are commonly less suitable or unsuitable for the production of crops for people. Non-ruminant animals (pigs and poultry) efficiently convert plant energy and protein products (grains, protein meal, byproducts and residual products from biofuels and processing industries) and animal-derived co-products (fats and tallow, blood plasma, outdated and waste human food products) into protein and vitamin-rich meat and egg products. The nutrient density of food animal products plays a vital role in the diets of people around the world, supplying valuable sources of high-quality protein, fatty acids, vitamins, and minerals.

Research focusing on livestock production efficiency has far-reaching effects, as efficiency encompasses all aspects of food animal production. Efficiency improvements involve fundamentally understanding relationships between animal biology and the nutrient and health values of feed and forage resources used to support animal growth, development and reproduction; the effective utilization of environmental resources, including optimal housing and management; the appropriate use and assessment of natural resources and ecosystem services: and the ability to meet consumer expectations for food animal use. ARS scientists provided vast contributions and enhancements to food animal production efficiency, helping ensure domestic and international food security. Research outcomes contribute to improved human health by reducing the real cost of nutritionally valuable animal products, increasing the availability of animal food products to populations most in need.

The contributions of animal-derived products to improved human health are clear, but food animal production sectors have challenges to address. Recent reports discuss the potential negative impact of food animal production on the environment, including contributions to greenhouse gas generation, algal blooms resulting from feed and manure runoff, degradation of wildlife habitat, and the prevalence of pathogenic and antibiotic resistant microorganisms in the environment from animal waste. Animal production sectors also face the perception that technologies improving the efficiency of animal production simultaneously compromise the health and well-being of food animals. These negative perceptions have resulted in regulations redefining how food animals are raised within some areas of the United States, while simultaneously creating new challenges to food safety (greater bacterial concerns in floor-raised vs. caged hen housing), animal care, and well-being (aggression and an associated increase in injury risk for group-housed breeding swine and laying hens). These regulations also change the ability to control disease in food animal populations because of restrictions on using antibiotics that are considered medically important to humans. These current and emerging challenges require attention and focus to maintain sustainable food animal production sectors and continue the efforts toward global food security.

Key drivers and focal areas for research within NP101 include:

- Capture and effective use of feed and forage resource nutrients from traditional and emerging byproduct feedstocks.

- Enhanced digestive system and rumen function and the associated improvements in animal health, well-being, and environmental impact.
- Evaluation and optimization of systems-based approaches to food animal production, addressing reproduction, genetic optimization, and management practices that support producer sustainability and improved product quality and value for the consumer.
- Discovery, verification, and adoption of cost effective, labor-saving, welfare appropriate new technologies.
- Application of advanced analytic capabilities and statistical modeling to utilize Big Data and bioinformatics capabilities more effectively.
- Germplasm preservation for effective assessment and conservation of species genomic variation, providing industry and producer partners with unique and valuable resources for the future.
- Expanding knowledge and application of animal and microorganism genomes, phenomes, gene expression, and the associated key genes, pathways, and associations that improve selection response and offer genome editing targets.
- Focused efforts in precision livestock applications that monitor individual animal needs, identify optimal housing conditions, and help explain and modify the array of environmental factors that influence stress, health, and behavior of food animals.

Future Directions

Fiscal Year (FY) 2023 represents the initiation of the FY 2023-2027 research cycle. Research projects and specific experiments are continually enhanced through extending existing biological knowledge to new areas, technological advances that improve the depth and precision of investigation, and the application of critical advances in bioinformatics, artificial intelligence, and machine learning algorithms that improve scientific capacity. Highlighted research accomplishments express the application of these scientific advances. NP101 scientists are committed to scientific discovery that solves problems and the delivery of scientifically validated information that can be rapidly adopted by the animal production sectors.

United States and International Collaborations

Scientists in NP101 are actively engaged in research collaborations spanning the globe. These collaborations provide leadership and guidance to national and international consortia, advance collaborative research, and represent U.S. interests and expertise in the global scientific community. In FY 2023, formal research collaborations were conducted with Australia, Austria, Brazil, Burkina Faso, Canada, Denmark, Ethiopia, France, India, Iran, Italy, Japan, Malawi, Mongolia, New Zealand, Peru, South Africa, Spain, Sweden, Uganda, and the United Kingdom.

ARS scientists and research locations within NP101 are located very near, and commonly on, the campus of U.S. land-grant universities, which fosters formal and informal agreements and collaborations within and across ARS units. These relationships support interactions that formally or informally tie USDA ARS scientists to nearly every U.S. land-grant (1862, 1890, and 1994) and non-land grant agricultural university.

FY 2023 Outreach Activities

NP101 Scientist Academic Outreach and Mentorship

Undergraduates	Graduate Students	Post-Docs	Scientist Advisors	Mentors	Adjunct Professors/Other
1	14	12	21	8	18

NP101 Student-Related Outreach Activities

	Presentation to Schools	Student Tours & Visits to ARS Locations	Science Fair Participation
Number of Activities	1	22	1
Number of Students	35	679	50

NP101 General Outreach to Stakeholders and the Public

Name of Activity	Number of Activities	Number of Participants
Presentation to Local/Community Groups	7	281
Training/Demonstration	6	278
Webinars	4	213
Presentation to Practitioner/Industry/Producer	13	433
Workshops	3	94
Stakeholder Meetings	8	310
Teaching (Courses)	4	84
STEM Events	3	816

FY 2023 Personnel Updates

New Scientists in 2023

- **Dr. Jessica Pempek** joined the Livestock Behavior Research Unit, West Lafayette, Indiana. Dr. Pempek will conduct animal welfare and behavior research with a primary focus on the dairy production sector.
- **Dr. Bailey Engle** joined the Genetics and Genomics Research Unit, Clay Center, Nebraska. Dr. Engle will focus on beef cattle genetic improvement strategies.

- **Dr. Jennifer McClure** joined the Cell Wall Biology and Utilization Research Unit with the Dairy Forage Research Unit, Madison, Wisconsin. Dr. McClure will focus on rumen development and microorganism change within the rumen of dairy heifers from birth through first lactation.

The following scientists in NP101 received prominent awards in 2023

- **Dr. Timothy P. L. Smith** was inducted into the USDA ARS Science Hall of Fame, honoring his research accomplishments that have shaped the direction and evolution of ARS animal genomics programs.
- **Dr. Tommy Wheeler** received the Nebraska Beef Industry Research Award from the Nebraska Cattlemen Foundation.
- **Dr. Jay S. Johnson** received the American Society of Animal Science Early Career Achievement Award and the USDA ARS Outreach, Diversity, and Equal Opportunity Award.
- **Dr. Jeremy Marchant** received the International Society of Applied Ethology Honorary Fellow Award,

The following scientists retired in 2023

- **Dr. Harvey Freetly**, Research Leader, Nutrition, Growth, and Physiology Research Unit, Clay Center, Nebraska.
- **Dr. Kenneth Turner,** Research Scientist, Livestock, Forage and Pasture Research Unit, El Reno, Oklahoma.

Major Accomplishments in 2023

Summaries of significant research accomplishments for FY 2023 are highlighted in the following materials. The accomplishments are provided in alignment with the Food Animal Production 2023-2027 Action Plan Components, Problem Statements, and Anticipated Products sections. Accomplishments presented are a subset of information provided in project annual reports. To view all the accomplishments for each project within the program, please visit the USDA ARS NP101 website.

Component 1: Increase Food Animal Production Efficiencies, Food Animal Well-Being, and Adaptation of Food Animals to Diverse Production Systems.

Problem Statement 1A: Improve the Efficiency of Food Animal Growth and Nutrient Utilization.

Clover compound reduces bacterial resistance in cattle rumen.

Forage Animal Production Research Unit, Lexington, KY.

In the cattle industry, where grain-based diets are commonly fed prior to harvest, studies show increased dietary concentrations of cracked corn, in the absence of antibiotics, are normally associated with an increased number of antibiotic resistant bacteria in the rumen (first "stomach"). Bacterial strains that can release antibiotic compounds from their intracellular space are thought to contribute to this form of antibiotic resistance. This can have detrimental effects on the animal and potentially on the contamination of animal food products. ARS researchers in Lexington, Kentucky, fed cattle diets with increasing concentrations of cracked corn to mimic the expected increase in antibiotic-resistant bacteria, and added *Biochanin A*, a naturally occurring red clover compound that blocks the bacterial resistance mechanism, to see if it affected bacterial resistance to the antibiotic tetracycline. The *Biochanin A* additive reversed tetracycline resistance in rumen bacteria, with up to 99.9 percent fewer rumen bacteria identified as resistant to tetracycline when compared to rumen bacteria in cattle fed the control diet. These results indicate that *Biochanin A* derived from clover, a common forage plant, can reduce the number of antimicrobial-resistant bacteria in the gastrointestinal tracts of cattle, a finding that will increase the number of treatment options and improve treatment efficacy in production settings. The addition of Biochanin A as a feed additive offers great promise for improving animal health in production systems.

Problem Statement 1B: Improve Food Animal Reproductive Efficiency.

Cryopreservation of turkey germplasm using optimized ovarian tissue vitrification.

Beltsville Agricultural Research Center, Animal Biosciences and Biotechnology Laboratory, Beltsville, MD.

Vitrification is a freezing process used to preserve reproductive tissue and for germplasm conservation. Preserving both the female and male sex chromosomes in poultry requires collecting, preserving, and transplanting ovarian tissue to recipient birds. The success rate for ovarian tissue preservation requires optimal freeze-thaw protocols and the ability to screen for low-quality donor samples before tissue is transplanted in the recipient. ARS scientists in Beltsville, Maryland, utilized an *in ovo* culture system to compare fresh, poorly frozen, and optimally frozen immature turkey ovaries and identified three novel gene biomarkers for improved ovarian development after transplantation. These three gene biomarkers provide a broad assessment of ovarian tissue viability, function, and damage post-freezing. This breakthrough in turkey ovarian cryoconservation is the first report of a screening method to identify poor-quality donor ovarian samples in turkeys. The new technology will ensure transplantation of ovarian samples with high development potential, which will greatly reduce breeder costs, vastly improve turkey cryopreservation success rates, and help conserve genetic variation within a small population base.

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

Improving pig welfare through informed environmental management.

Livestock Behavior Research Unit, West Lafayette, IN.

Climate change and more frequent, intense, and longer weather events create animal welfare concerns for livestock, particularly heat stress challenges that threaten the profitability and sustainability of U.S. and global livestock enterprises. Pigs are particularly sensitive to the negative effects of heat stress, which can be detrimental to their health, productivity, and welfare. Pig producers use several commercially available cooling technologies to mitigate heat stress; however, they need real-time, readily accessible information on weather and in-building conditions to optimize mitigation strategies. ARS researchers in West Lafayette, Indiana, and University of Illinois and Purdue University collaborators developed the smartphone application *HotHog* to predict thermal comfort and stress in pigs. *HotHog* technology helps producers more accurately predict, plan, and implement best practices to reduce the detrimental impacts of heat stress across a pig's lifespan. The *HotHog* app is freely available to the public for iOS and Android through the Apple App Store or Google Play. Producers in more than 40 countries are now using this modern, science-based tool to improve pig comfort, health, and welfare and increase potential profits in swine production.

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

Problem Statement 2A: Develop Bioinformatic and other Required Capacities for Research in Genomics and Metagenomics.

First complete mammalian X- and Y-chromosome assembly for cattle, sheep, and goats.

Beltsville Agriculture Center, Animal Genomics and Improvement Laboratory, Beltsville, MD.

US Meat Animal Research Center, Genetics and Animal Breeding Research Unit, Clay Center, NE.

Sex chromosomes (X and Y in mammals) contain the unique and essential genes that define and differentiate females and males of a species. Precision mapping and gene identification on sex chromosomes was hampered due to technical limitations in sequencing technology, significantly slowing genetic improvement in livestock. ARS scientists in Clay Center, Nebraska, and Beltsville, Maryland, collaborated with researchers at the University of Idaho, Utah State University, the University of Missouri, and the National Institutes of Health to create and analyze the first complete sex chromosome assembly map in cattle, sheep, and goat species. Findings identified surprising differences in the genes, their varied arrangement in ruminants, and how they vary between ruminants and primates. This pioneering research opens the door for improving analyses of sex-specific trait expression (e.g., milk yield, semen volume) and inheritance patterns, increasing the accuracy of genetic selection, and increasing the fundamental knowledge of species similarity and differentiation in sex chromosomes. Livestock producers will immediately benefit from using new genomic information in genetic evaluation and selection programs, which will advance the accuracy and rate of genetic improvement for reproduction, growth and development, and production efficiency traits that influence economic, environmental, welfare, and societal outcomes.

Complete ruminant genome assemblies greatly enhance genetic discovery.

Beltsville Agriculture Center, Animal Genomics and Improvement Laboratory, Beltsville, MD.

US Meat Animal Research Center, Genetics and Animal Breeding Research Unit, Clay Center, NE.

1: Photo Credit: Dr. Timothy Smith – Scottish Highland Cattle an important genetic resource population.

Genetic variation, whether from natural evolutionary processes or selection to develop livestock breeds, is essential to match an animal and its environment. In modern livestock production, information is needed on effectively using genetic resources for the efficient and sustainable conversion of natural resources into human food. Advanced genomic tools now allow more than 99 percent of genes to be identified, providing scientists and the livestock producers they serve with unmatched resources to match genetics more effectively to production environments and management. ARS scientists in Beltsville, Maryland, and Clay Center, Nebraska, lead global Telomere-to-Telomere (T2T) genome assembly and Bovine Pangenome research consortia, which include more than 90 cutting-edge researchers at 58 institutions in 27 countries, in an effort to fully characterize genomic variation within and across species. To date, ARS researchers completed T2T whole genome assemblies for 32 of 50 prioritized bovine beef- and dairy-type breeds, including *Bos taurus* and *Bos indicus* species, as well as rare, native, and modern breeds from across the globe. In addition, ARS scientists lead T2T assembly efforts in poultry, sheep, goats, and swine. These ARS-led comparative research efforts will expand the scientific understanding of functional biology, identify causative genes and gene interactions, and expand research in both animal and human species, ultimately improving access to and the affordability of animal food products.

Problem Statement 2B: Characterize Functional Genomic Pathways and their Interactions.

A resource for pig genotype-tissue expression.

US Meat Animal Research Center, Genetics and Animal Breeding Research Unit. Clay Center, NE.

Animal performance results in part from genetic makeup and how genes are regulated and expressed. Characterizing when, how, and to what extent genes are expressed in different body tissues enables scientists to better understand how genotypes affect the development of desirable phenotypes for animal production settings. The Farm Animal Genotype-Tissue Expression (FarmGTEx) project is an international consortium charged with developing a comprehensive public resource to support the study of tissue-specific gene regulation in domestic animal species. ARS researchers in Clay Center, Nebraska, are primary contributors to the pilot phase of PigGTEx; they have processed and provided repository information for more than 9,000 RNA-sequence and more than 1,600 whole-genome sequence samples encompassing more than 100 pig tissues. Researchers used this information to decipher regulatory mechanisms underlying about 80 percent of the genetic associations for more than 200 complex pig phenotypes and demonstrated similarities between the genetic expression of humans and pigs. The PigGTEx project will serve as a critical genetic/genomic resource for researchers in the swine and human genomics research communities as they address animal production efficiency and human biomedical advances, respectively.

Discovery of a major new mutation causing dairy calf death loss.

Beltsville Agriculture Center, Animal Genomics and Improvement Laboratory, Beltsville, MD.

U.S. dairy producers recently identified an inherited condition in newborn calves termed "recumbency'" that makes young calves unable to stand and results in higher death rates. Enhanced genome sequencing, extensive genomic sampling, and complete pedigree relationships allowed scientists to rapidly identify the causative mutation and respond to industry with approaches to eliminate the gene(s) from the cattle population. ARS scientists in Beltsville, Maryland, and Pennsylvania State University collaborators investigated and identified "recumbency" as a homozygous recessive genetic condition in a gene affecting muscle movement. Researchers traced the source of this defect back many generations, identifying multiple, high genetic merit sires that carry the mutation and which have produced many daughters in many herds through artificial insemination. This finding indicated the recessive mutation was likely distributed across a high percentage of the Holstein population. Holstein breeders and producers now routinely utilize the direct DNA test to select animals free of this mutation and utilize pedigree tracing to identify older animals that warrant testing to eliminate the mutation from the population.

Problem Statement 2E: Develop Techniques for Genetic Modification and Genetic Engineering of Food Animals and Evaluate their Efficacy.

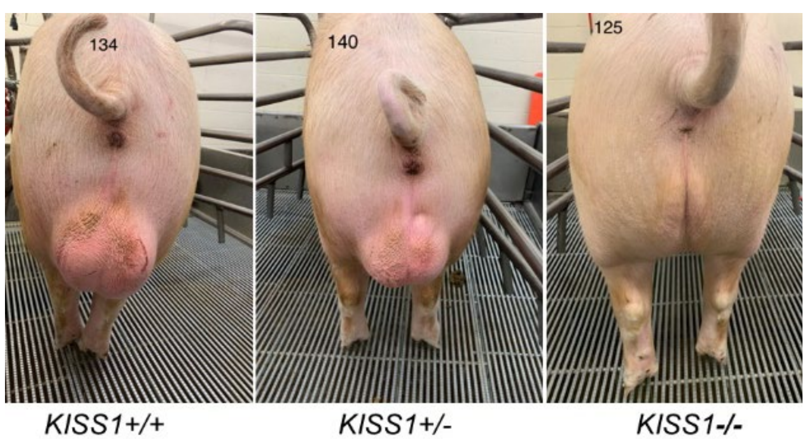
Porcine intestinal and liver organoid cultures as models for testing genome editing in pigs.

Plant Genetics Research Unit, Columbia, MO.

Infectious diseases in pigs cause billions of dollars in economic losses, are detrimental to animal welfare, and threaten the human food supply. Developing countermeasures to combat viral and bacterial disease requires the development and use of research animals that can be challenged with a pathogen, which is expensive and time consuming. ARS researchers in Columbia, Missouri, successfully established three-dimensional cell cultures, called organoid cultures, for intestine and liver. These organoid systems mimic live animal tissue more closely than individual or combined cell cultures and provide an *in vitro* model for testing viral and bacterial infectivity in the presence of genomic edits prior to conducting research with live animals. As a result, these organoids provide a less expensive screening tool to identify important genes involved in pathogen resistance or infectivity and align with universal efforts to reduce the number of live animals required for research. This innovation will accelerate the development of countermeasures that improve disease resistance in livestock.

Genome editing to develop castration-free pigs.

US Meat Animal Research Center, Livestock Bio-systems Research Unit, Clay Center, NE.



2: Photo Credit: Dr. Clay Lents. KISS1 +/+ = Homozygous, Normal Male External Genitalia; KISS1 +/- = Heterozygous Gene Edit, Normal Male External Genitalia; KISS1 -/- = Homozygous Gene Edit, Male External Genitalia Underdeveloped.

Male pigs develop aggressive behaviors, and their meat takes on "boar taint" during sexual development, so male piglets destined for pork production are castrated to prevent these outcomes. ARS scientists in Clay Center, Nebraska, partnered with industry and university collaborators and identified KISS1 as a key gene responsible for reproductive development. They found that a genomic edit of the KISS1 gene prevented the development of testes (KISS1 -/-) in male pigs but did not affect any other characteristics of male pig development. These results demonstrate the potential to use genome editing for genomic-based alternatives to castration that will lead to improved animal welfare for market pigs and maintain a high level of consumer acceptance for pork products.

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.

Postmortem gene expression demonstrated in pork muscle.

US Meat Animal Research Center, Meat Safety and Quality Research Unit, Clay Center, NE.

Gene expression was generally believed to stop at the time of harvest and therefore did not influence postmortem glycolysis nor contribute to postmortem environmental effects on quality. However, many meat quality attributes that influence processing and eating quality are profoundly influenced by the postmortem environment. ARS scientists in Clay Center, Nebraska, determined that numerous genes in pork longissimus muscle are more highly expressed at 48 hours postmortem than at the time of harvest. Many of the genes that are highly expressed in the postmortem period code for proteins, indicating that the postmortem muscle continues to produce new proteins to maintain energy production. Genes that displayed increased expression coincided with previously reported genetic markers that could be used to select for improved quality in pork. This work represents a paradigm shift about gene expression in postmortem muscle and will lead to greater understanding of meat quality development. Moreover, this work will increase the effectiveness of genetic marker discovery for meat quality traits and postmortem management to further improve meat quality.