Food Animal Production (NP 101) Annual Report for 2022

Introduction

Vision: The vision for National Program 101 (NP 101), “Food Animal Production”, is that ARS will provide the scientific community and food animal industries with scientific information, biotechnologies, and best management practices that ensure 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.

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

Farm level income from food animal production contributes greatly to the U.S. rural economy through farm-gate cash receipts and the sales and transactions associated with allied industries, like animal feeds, farm supplies, germplasm provision and sales, and animal health related product sales. According to the most recent U.S. Census of Agriculture (2017), the National Agricultural Statistics Service reported cash receipts at the farm gate of $77.1 billion from 39.4 million cattle and calf sales, $35.2 billion in milk production sales from 9.35 million dairy cows, $26.3 billion from 254 million pig sales, $1 billion in sales (includes meat, wool, and milk) from 5.4 million sheep and goats, and $49.2 billion in poultry sales (includes turkeys, broilers, and eggs). Along with the direct economic contribution, food animals convert plant materials into animal products that are excellent sources of high biological value protein and contain nutrients like vitamin B12 that are essential for human health. Ruminant food animals (cattle and sheep) convert forages (e.g., grasses, alfalfa) that are not suitable for human consumption into nutritious human food products, utilizing lands that are also unsuitable or less suitable for human edible crop production. In addition, pigs and poultry convert plant energy and protein products and co-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, providing valuable sources of high-quality protein, fatty acids, vitamins, and minerals.

ARS scientists have provided vast contributions and enhancements to food animal efficiency and have helped ensure international food security and directly impacted human health by reducing the real cost of nutritionally valuable animal products, making animal products more available, especially to those populations most in need. The contributions to improve human health are clear, yet food animal production sectors have challenges to address. Recent reports draw attention to the potential negative impact of food animal production on the environment, including food animal contribution(s) to greenhouse gas generation, feed and manure derived nitrogen and phosphorus runoff resulting in algal blooms, degradation of wildlife habitat, and the contribution of animal waste to the prevalence of pathogenic and antibiotic resistant microorganisms in the environment. Animal production sectors also face the perception that technologies that improve the efficiency of animal production simultaneously compromise the health and well-being of food animals. In addition, regulations are redefining how food animals are raised within some areas of the United States, 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), and changes in the ability to control disease in food animal populations because of restrictions on use of 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.

Research focusing on livestock production efficiency has far-reaching impacts, as efficiency is an all-encompassing term in food animal production. Efficiency improvements involve a fundamental understanding of, and the interactions between: the biology of animal; the nutrient and health values of feed and forage resources used to support animal growth, development, and reproduction; and, the effective utilization of environmental resources including optimization of housing and management, the appropriate use of and consideration for natural resources and ecosystem services, and the ability to meet consumer expectations for food animal use. Key drivers and focal areas include:

- capture and effective use of nutrients from traditional and emerging feedstocks;
- enhanced gut and rumen function and the associated improvements in animal health and well-being;
- evaluation and optimization of production, reproduction, and product quality traits;
- discovery, verification, and adoption of new technology;
- enhanced analytical capabilities and statistical modeling to use 'big' data and bioinformatics;
- expanding knowledge of animal and microorganism genomes and phenomes to identify key genes, pathways, and associations that improve selection response and offer gene editing targets;
- and, focused efforts to monitor individual animal needs, identify optimal housing, and understand the myriad of environmental factors that influence stress, health, and behavior of food animals.

All with goals focused on offering solutions that ameliorate concerns for animals produced for food.

Improved efficiency directly reduces waste production and greenhouse gas emissions, decreases the impact on the land, water, and air resources while also continuing to provide food resources that are wholesome, safe, nutritious, and affordable. These outcomes are key to providing food to an expanding human population and offering sustainable profitability to the producer. Addressing efficiency, now more than ever, requires multi-disciplinary approaches applied to complex biological systems, application of technology that enhances research outcomes, the transfer of information to decision makers, and the adoption of scientifically proven best practices by livestock producers. Excellent scientists working with partners and stakeholders underpin the ARS-driven collaborative research efforts that provide solutions to known challenges and discover new science and technologies that support efficient and profitable food animal production.

The study of microorganisms is an essential focus of this program. Understanding their roles in food animal health and production will advance pathogen reduction strategies that influence human, animal, and environmental health and also contribute to ongoing efforts to reduce greenhouse gas emissions from food animal production systems.

Future Directions

Fiscal Year (FY) 2022 represents the completion of the FY 2018-2022 research cycle. The scientific advances made through these projects will continue to drive and expand research to be conducted in the newly initiated projects within the FY 2023-2027 Action Plan. The progressive National Program in Food Animal Production builds on successes and addresses the animal and associated non-animal influencers in the face of existing and emerging challenges. Scientific advances have allowed greater depth of knowledge of biological function than ever before, and ARS scientists continue to be scientific leaders in discovery and application of these findings to food animal production. Artificial intelligence, autonomous monitoring and measurement capabilities, and advances in bioinformatic analysis capabilities have and will continue to underpin future research and hasten delivery of solutions to food animal industries and consumers.

Program Funding, Collaborations, and Staffing

In FY 2022, NP 101 Food Animal Production had 93 full-time scientist positions working at 15 locations across the United States and conducting research on 27 appropriated research projects. In FY 2022, appropriated funding for NP101 was $60 million, with increased funding support for dairy cattle, gene editing, and silvopasture research efforts.

International and US Academic Collaborations

Australia, Austria, Belgium, Brazil, Burkina FASO, Canada, Denmark, Ethiopia, France, Guyana, India, Iran, Ireland, Israel, Italy, Malawi, Mexico, Mongolia, Netherlands, New Zealand, Nigeria, Poland, Russia, South Africa, Spain, Sweden, Switzerland, Uganda, United Kingdom.

Nearly every U.S. Land-Grant College and University, including multiple 1890 Universities and multiple Private Agricultural Universities

Outreach Activities

NP 101 Scientist Academic Outreach and Mentorship

Undergraduates	Graduate Students	Post-Docs	Scientist Advisors	Mentors	Adjunct Professors/Other
19	23	0	4	12	2

NP 101 and National Programs, Animal Production Program: Student-Related Outreach Activities

	Presentation to Schools	Student Tours/Visits to ARS Locations
Number of Activities	7	12
Number of Students	377	184

Animal Production Program: General Outreach to Stakeholders and the Public

Name of Activity	Number of Activities	Number of Participants
Presentation to Local/Community Groups	2	30
Training/Demonstration	6	66
Webinars	10	206
Presentation to Practitioner/Industry/Producer	4	58
Workshops	1	14
Stakeholder Meetings	7	139
Laboratory Review	2	2
Teaching (Courses)	0	0
Stem Events	0	0

Personnel

New Scientists in 2022:

Dr. Paula Chen, Research Physiologist, joined the Plant Genetics Research Unit, Columbia, Missouri. Dr. Chen's efforts will focus on the application of gene editing technology to expand and enhance efforts in genetic and genomic technology applications in food animal production with a primary focus on poultry species.

Dr. Carrie Wilson, joined the Range Sheep Production Efficiency Research Unit at Dubois, Idaho. Dr. Wilson's efforts will include a focus on genetic improvement in ewe productivity, the establishment and evaluation of new phenotypes for genetic selection, and optimized integration of phenotypic and genotypic data from breeder flocks to National Sheep Improvement Program genetic merit assessment processes.

Dr. Jennifer Thorson, joined the Nutrition, Growth and Physiology Research Unit, Clay Center, Nebraska.

Dr. Carolina Gonzalez-Berrios, joined Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana.

The following scientists retired in 2022:

Dr. Don Lay, Research Leader, Livestock Behavior Research Unit, West Lafayette, Indiana.

Dr. Jim Neel, Research Animal Scientist, Grazinglands Research Laboratory, El Reno, Oklahoma.

Dr. Andy Roberts, Reproductive Physiologist, Livestock and Range Research Laboratory, Miles City, Montana.

Major Accomplishments in 2022

Summaries of significant research accomplishments for Fiscal Year 2022 are highlighted in the following materials. The accomplishments are in alignment with the Food Animal Production 2018 – 2022 Action Plan components, problem statements, and anticipated products. 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 National Program 101 website: https://www.ars.usda.gov/animal-production-and-protection/food-animal-production/docs/annual-reports/

https://www.ars.usda.gov/research/project-list-by-program/?npCode=101Many 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 that otherwise could not be addressed.

Component 1: Improving Production and Production Efficiencies while Enhancing Animal Well-Being across Diverse Food Animal Production Systems

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

Modeling liver abscess formation to reduce antibiotic usage in cattle
Livestock Issues Research Unit
Lubbock, Texas

Liver abscesses in cattle result in significant economic losses (estimated $60 million annually) for producers and the beef packing industry due to reduced growth rate, increased incidence of rumen acidosis with negative impacts on animal health and welfare, and reduced carcass value. Unfortunately, liver abscesses are only clearly identified at harvest on inspection of the organs, limiting live animal research that may identify cause and solutions. ARS scientists in Lubbock, Texas, and university collaborators have developed a real-world, live animal liver abscess model that more closely aligns with the natural development of abscesses in cattle. Through diet alteration and oral infusion of naturally occurring bacteria, scientists are now able to increase the ability to identify cattle having liver abscesses and evaluate intervention and mitigation strategies to reduce the liver abscesses in beef production systems. The model will allow testing of alternatives to antibiotic treatment, contributing to goals of reducing the need for antimicrobial use and the potential for development of resistance, while also improving cattle health and wellbeing in concert with improving economic returns at the farm and packer levels. (NP101, C1, PSA and C, Project No. 3096-32000-008-000D)

New, highly protective vaccine for Marek's Disease
U.S. National Poultry Research Center, Endemic Poultry Viral Diseases Research Unit
Athens, Georgia

Repeated emergence of more virulent Marek's Disease Virus (MDV) strains in vaccinated chicken flocks prompted urgent research focused on enhanced Marek's Disease (MD) vaccines. ARS researchers in East Lansing, Michigan, and Athens, Georgia, collaborated with a researcher at Simon Fraser University (Vancouver, Canada) and used innovative, recombinant DNA technology and naturally occurring genetic variation in a targeted gene to develop a new, highly protective MD vaccine candidate. Genomic discoveries and newly developed recombinant vaccine methodology have allowed researchers to respond quicky to ever-changing and emerging disease threats on the farm. A next step will include regulatory approval, offering the U.S. poultry producers the new MD vaccine to reduce mortality and morbidity; improve poultry health, well-being, and production efficiency; and support economic sustainability of the poultry industry. (NP101, C1, PSA, Project No. 6040-31320-010-000D)

Legume supplements reduce vasoconstriction associated with fescue toxicosis
Forage Animal Production Research Unit
Lexington, Kentucky

Legumes are commonly utilized in livestock production to improve diet quality and often contain vasodilatory isoflavones shown to alleviate fescue toxicosis in goats and grazing cattle. However, legume species vary in both isoflavone concentration and composition. ARS researchers in Lexington, Kentucky, evaluated isoflavone supplementation via red clover, white clover, and soybean meal could mitigate vasoconstriction associated with fescue toxicosis in goats. Rumen fistulated wether goats fed supplemented diets were subjected to a fescue toxicosis challenge with toxic tall fescue seed, evaluating carotid artery area using Doppler ultrasonography. While all isoflavone treatments partially alleviated vasoconstriction, red clover, with the greatest concentration of isoflavones, was the most effective (+40 percent artery area). The findings demonstration that legume-derived phytochemicals red clover, white clover, and soybean meal, when supplemented in ruminants consuming toxic tall fescue, can reverse fescue toxicosis and improve animal health and productivity. (NP101, C1, PSA, Project No. 5042-32630-003-000D)

Problem Statement 1B: Improving Reproductive Efficiency

Renewed emphasis on replacement heifer nutrition to improve reproductive efficiency
Range and Livestock Research Unit
Miles City, Montana

Almost half of the reproductive loss in cattle comes from early embryo death that occurs between 8 and 16 days after fertilization, extending the normal breeding season and adding feed costs that do not generate an economic return. Replacement heifers, or virgin cows, are developed and grown post weaning to replace the cow herd. Advances in nutrition science, coupled with prescribed use of added nutritional supplementation can improve reproduction efficiency in replacement heifers. ARS researchers in Miles City, Montana, studied the impact of nutritional energy levels 30 days prior to and 7 days following breeding to determine the impact on embryo development. When less energy was fed for 30 days before breeding, reproductively essential hormone levels were reduced, and embryo development was slower. When less energy was fed for 7 days after breeding, embryo quality was reduced. Lower quality embryos and embryos that grow more slowly are less likely to result in pregnancy success. Results indicate that cow-calf producers will benefit greatly from providing sufficient energy in the month prior to and the week following breeding of replacement heifers to improve reproductive success and reduce the extremely high cost of producing cow herd replacement females. Greater pregnancy rates will increase revenue and can improve profitability. (NP101, C1, PSA and B, Project No. 3030-31000-018-000D)

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

Heat stress alters swine brain function in utero
Livestock Behavior Research Unit
West Lafayette, Indiana

Increasing spatial and temporal global temperatures threaten global animal agriculture, including reductions in swine health, productivity, and welfare during prenatal development and postnatal life. ARS researchers in West Lafayette, Indiana, building on their previous research, found that in utero heat stress increased the size of the hypothalamus region of the pig's brain, the area that controls physiological stress responses. In utero heat-stressed piglets that were measured post birth had physiological responses indicative of greater stress when common production practices (e.g., transport, social mixing, routine handling) were evaluated, putting them at a greater risk of reduced welfare. These findings represent a significant scientific discovery regarding underlying impacts of in utero stress and underpins future research direction. With the new knowledge, the research community can more effectively target pharmaceutical, nutritional, and/or management-based heat stress mitigation strategies to improve swine welfare in the face of climate change. (NP101, C1, PSC, Project No. 5020-32000-013-000D)

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

New methodology results in unprecedented microbiome findings
U.S. Dairy Forage Research Center, Cell Wall Biology and Utilization Unit;
U.S. Meat Animal Research Center, Genetics and Animal Breeding Research Unit;
Beltsville Agricultural Research Center, Animal Genomics and Improvement Laboratory.
Madison, Wisconsin; Clay Center, Nebraska; Beltsville, Maryland, respectively.

ARS scientists in Madison, Wisconsin; Clay Center, Nebraska; and Beltsville, Maryland, led studies conducted with researchers from the Netherlands, Israel, Russia, and industry that resulted in a revolutionary new microbiome DNA screening method that revealed previously indistinguishable differences between microorganism strains within the livestock microbiome. ARS scientists worked with bioinformaticians at Pacific Biosciences to develop the open-source software tool, MAGPhase, which automates genetic sequence variant discovery and validation in the microbiome. The improved accuracy enabled the MAGPhase algorithm to identify clusters of sequence variants that represent divergent strains and types of microbes within the microbiome that may harbor antibiotic resistance or pathogenesis genes. The team assembled 428 complete genomes of microbes obtained from a GI tract sample of a single individual, a record for a scientific field that previously celebrated the assembly of 10 genomes from one individual. These innovations created a new benchmark for microbiome studies and are serving as the foundation for current applications and new surveys in human clinical and agricultural microbial systems. (NP101 C2, PSA; Project Nos: 5090-31000-026-000D, 8042-31000-001-000D and 3040-31000-100-000D)

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

Optimized cryopreservation of turkey genetic resources

Beltsville Agricultural Research Center, Animal Biosciences and Biotechnology Laboratory
Beltsville, Maryland

For most livestock species, sperm cryopreservation effectively captures the entire genome. However, in birds, female chromosomes determine gender, so complete genome capture and preservation entails collecting female gonads as well as sperm. Effective cryopreservation is not possible for eggs, so reproductive biology expertise driving female gonad retrieval, preservation, and re-introduction are critical needs in the turkey and across avian species. ARS scientists in Beltsville, Maryland, in collaboration with scientists in Canada, perfected turkey female gonad (ovary) retrieval timing in chicks and further established an optimized surgical method and identified timeframe for transplanting ovaries to recipient birds. Results indicate that 91 percent of ovarian grafts were successful if tissue was collected from 7-day old donors and implanted into 2-day old recipients under the surgical process. This discovery represents a major scientific advancement, offering industry and research institutions a powerful tool to preserve valuable turkey lines in frozen form for future use. (NP101, C2, PSC, Project No. 8042-31000-110-000D)

Problem Statement 2D: Develop and Implement Genetic Improvement Programs using Genomic Tools.

Beef composite breed composition not stable over time

Range and Livestock Research Unit
Miles City, Montana

Composite cattle breeds are commonly used in the U.S. beef industry to combine individual pure breed strengths and benefit from the heterosis (hybrid vigor) obtained by crossing divergent genetics. In statistical theory and classic quantitative genetics, composite breeds under no selection pressure are thought to maintain consistent breed composition percentages from generation to generation following initial breed development. Genomic tools and technological advances now make lineage tracing and breed composition estimation more powerful. ARS scientists in Miles City, Montana, and Fort Collins, Colorado, evaluated genomic breed composition over time in an ARS three-breed composite formed in the 1980s and their results indicate that the current genetic composition changed substantially from quantitative estimates. These changes show that original breed proportions are not stable over generations; environment and management, independent of artificial selection, influence the alleles that remain over extended periods of time; and favorable alleles originating from the most environmentally adaptive breeds increase in frequency. This finding suggests that there is an opportunity to identify genetic types that are more fit for a given environment and supports application of genetic by environment by management principles in U.S. beef cattle production. (NP101, C2, PSD, Project Nos. 3030-31000-018-000D and 3012-31000-006-000D)

Genetic Resilience to Ovine Progressive Pneumonia disease

U.S. Meat Animal Research Center, Livestock Bio-systems Research Unit
Clay Center, Nebraska

Ovine Progressive Pneumonia (OPP) is a progressive, incurable viral disease of sheep that can also propagate susceptibility to secondary diseases, ultimately resulting in millions of dollars of annual economic losses to the sheep industry due to death and productivity losses. ARS researchers at Clay Center, Nebraska, evaluated the impact of genotype combinations, or diplotypes, of the TMEM154 gene on OPP infection status and ewe lifetime productivity using data from three long-term, multi-generational studies. In a common environment and with similar levels of natural virus exposure, less than 10 percent of ewes with the favorable genotype became OPP infected through 5.5 years of age, whereas greater than 80 percent of ewes with the unfavorable genotype were infected by 3.3 years of age. Ewes with the favorable genotype produced 2.1 more lambs and 40 kg greater total weight of weaned lambs over a five-year period. Genomic identification of TMEM154 favorable allele and homozygosity status, and subsequent genetic selection for homozygosity for the favorable TMEM154 gene will improve flock health and lifetime productivity, with an estimated economic impact of $171 per ewe in additional lifetime revenue. Producers are now able to capture this impact through testing and selection. (NP101, C1 and 2, PS1B and 2D, Project No. 3040-31000-101-000D)

Advanced bovine genome assembly enhances genetic merit prediction.

Beltsville Agricultural Research Center, Animal Genomics and Improvement Laboratory;
U.S. Meat Animal Research Center, Genetics and Animal Breeding Research Unit.
Beltsville, Maryland and Clay Center, Nebraska

Breeding better cattle through genomics requires enhanced, informative genome knowledge from multiple, diverse breeds of cattle. Previously, a single Hereford cow provided the sole genomic reference, critically limiting knowledge of genomic variation among individual cattle and breeds. Led by ARS scientists in Beltsville, Maryland; Madison, Wisconsin; and Clay Center, Nebraska, the Bovine Pangenome Consortium used a novel trio-binning method, employing genomic data from two parents and an offspring (the trio) to develop greatly improved genome assembly within breeds. The Consortium published 11 breed-specific reference assemblies in noted journals, characterizing breeds with global economic impact, and noted genetic variation (Brahman and Angus, Highland and Yak, Bison and Simmental, original Braunvieh, Nellore and Brown Swiss, and Gaur and Piedmontese). Collectively, these genome assemblies rival the most complete and accurate vertebrate genomes ever produced. Scientists have already used these assemblies to identify novel trait-associated variation, using the information to increase accuracy of genetic merit prediction and selection for important production traits in target populations and the farm level. The Bovine Pangenome Consortium has expanded to over 90 members at 58 institutions in 27 countries. (NP101, C2, PSA and D, Project Nos: 8042-31000-001-000D, 5090-31000-026-000D and 3040-31000-100-000D)

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

Validated biomarkers help define variation in beef quality

U.S. Meat Animal Research Center, Meats Safety and Quality Research Unit
Clay Center, Nebraska

Most of the variation in lean meat color, tenderness, and flavor cannot be fully explained with existing technical capabilities, resulting in unpredictable eating quality experiences for consumers. Recently, novel biomarkers associated with muscle metabolism and cellular stress response have been identified that may explain measurably more of the variation in meat quality traits. ARS scientists in Clay Center, Nebraska, verified that candidate biomarkers can be used to predict variation in beef tenderness, flavor, and color and explain previously unaccounted for variation in these traits. Connecting biomarkers to fundamental biological mechanisms responsible for variation in meat quality will lead to genetic selection approaches that improve quality, increase consumer satisfaction and purchases, and add millions of dollars in revenue to the U.S. beef industry through increased demand for high quality beef products. (NP101, C3, PSA, Project No. 3040-31430-006-000D)