Multistate Research Activity Accomplishments Report

Project/Activity Number: NC-1206
Project/Activity Title: Antimicrobial Resistance
Period Covered: Feb 11, 2019 – Dec 10, 2020
Date of This Report: February 1, 2021
Annual Meeting Date(s): Dec 10, 2019

NC1206 Objectives

1. Enhance surveillance and monitoring of antibiotic resistance and develop improved diagnostic tests.
2. Determine the ecology and mechanisms involved in resistance and transmission of resistance.
3. Develop and evaluate interventions (including alternatives to antibiotics) that reduce antimicrobial resistance in food production systems.
4. Quantify animal health, public health, social, economic, and environmental impacts of antimicrobial interventions in food production systems.
5. Create and deliver programs on antibiotic stewardship in food production systems through education and outreach.

Participants Attending the Meeting:

- Advisor, NIFA representatives, and external speakers (5)

George Smith (smithge7@msu.edu) – Administrative advisor, Michigan State University
Kathe Bjork (kathe.e.bjork@usda.gov) – NIFA representative
Steven Smith (steven.i.smith@usda.gov) – NIFA representative
Mark Carter (mark.carter@usda.gov) – NIFA Division Director in Food Safety
Heather Fowler (hfowler@pork.org) – National Pork Board

- NC 1206 members (21 attendees, 14 presented *)

* Bing Wang (Chair, bing.wang@unl.edu) – University of Nebraska-Lincoln
Erika Ganda (Secretary, ganda@psu.edu) – Pennsylvania State University
* Timothy Johnson (outgoing Chair, john2185@purdue.edu) – Purdue University
* Renata Ivanek (past Chair, ri25@cornell.edu) – Cornell University
* Paolo Moroni (pm389@cornell.edu) – Cornell University
* Jeongming Song (js2957@cornell.edu) – Cornell University
* Loren Tauer (lwt1@cornell.edu) – Cornell University
Yrjo Tapio Grohn (ytg1@cornell.edu) – Cornell University
Yung-Fu Chang (yc42@cornell.edu) – Cornell University

* Paul Plummer (pplummer@iastate.edu) – Iowa State University
* Michelle Soupir (msoupir@iastate.edu) – Iowa State University
* Qijing Zhang (zhang123@iastate.edu) – Iowa State University
* Sophia Kathariou (skathar@ncsu.edu) – Iowa State University
Hossam Abdelhamed (abdelhamed@cvm.msstate.edu) – Mississippi State University
* Sharif Aly (saly@ucdavis.edu) – University of California at Davis
* Emmanuel Okello (eokello@ucdavis.edu) – University of California at Davis
Richard Van Vleck Pereira (rvpereira@ucdavis.edu) – University of California at Davis
Terry Lehenbauer (tlehenbauer@vmtrc.ucdavis.edu) – University of California at Davis
* Stephanie Lansing (slansing@umd.edu) – University of Maryland
* Noelle Noyes (nnoyes@umn.edu) – University of Minnesota
Xu Li (xuli@unl.edu) – University of Nebraska-Lincoln

Brief Summary of Minutes of Annual Meeting:

- Welcome, introductions, agenda review: The meeting started with a welcome by Dr. Tim Johnson, who passed the Chair position to Dr. Bing Wang. Drs. Wang and Johnson co-moderated the meeting. Self-introductions were done among meeting participants. In addition to members enrolled in the project, Dr. George Smith, administrative advisor, and Dr. Kathe Bjork, NIFA representative of the project, attended the whole meeting.
- Administrative Update: Dr. George Smith gave an administrative summary and update, reiterating the emphasis on multistate collaborative efforts as the main mission of the project and the focus of annual reports.
- State report highlights: A total of 14 participants from 7 states updated the group with progresses in antimicrobial resistance related activities in research, extension, and education.
- Invited presentation: Outside speaker, Dr. Heather Fowler from National Pork Board, presented the antimicrobial stewardships in swine industry from one health perspective and detailed activities conducted and funding opportunities provided by National Pork Board for combating antimicrobial resistance issues.
- NIFA updates: Drs. Kathe Bjork, Steven Smith, and Mark Carter provided updates regarding AFRI funding programs and personnel changes at NIFA USDA, with a focus on the Divisions of Animal Systems and Food Safety, covering programs supporting antimicrobial resistance related research.
- Elections: Dr. Erika Ganda will serve as the project secretary for next year cycle, which was supported and confirmed by the group.
- Future plans: Group members shared prior experience/thoughts and discussed possible strategies to further strengthen multistate collaborations among the group, including coauthoring on critical review papers and grant plans.

Impact:

Antimicrobial resistance is a complex problem that must be addressed by taking a one-health approach, including aspects of animal, human, and environmental health.

To help understand and mitigate antimicrobial resistance, the NC1206 research group has made strides studying several aspects of antimicrobial resistance, including improving the understanding of the ecology and transmission of antimicrobial resistant bacteria and resistance genes, antimicrobial resistance detection, evaluation of alternatives to antibiotics, and social aspects of antimicrobial resistance, including farmer, veterinarian, and consumer perceptions.

The research group of NC1206 has also been very active in education and outreach, creating several extension materials, a conference on the social aspects of antimicrobial resistance, a social media initiative to educate the general public, and a creation of a new graduate course focused on antimicrobial resistance and one-health.

The efforts put forth by our group not only improve our understanding of the mechanisms and potential interventions to mitigate antimicrobial resistance, but also lay the groundwork for increased education and communication about antimicrobial resistance between researchers, farmers, veterinarians, the general public, and the next generation of experts in public health.

Accomplishments:

iAMResponsible [Objectives 4 and 5]

This was a collaborative education and extension effort about antimicrobial stewardship that was developed by several institutions in Maryland, Nebraska, New York, and Michigan.

A workshop was organized around antimicrobial resistance, social science, economics, and communication. This workshop resulted in a publication involving seven different institutions: University of Pennsylvania, Mississippi University for Women, Cornell University, The Ohio State University, Iowa State University, and Simon Fraser University.

A social media initiative was also developed as part of this effort: iAMResponsible is a rapidly growing initiative that is present on Twitter, YouTube, and Facebook.

National Institute of Antimicrobial Resistance Research and Education – NIAMMRE [Objectives 3 and 5]

With the objective of addressing prioritized gaps in knowledge related to antimicrobial use, stewardship, and resistance, a multi-organization consortium was founded by Iowa State University, University of Nebraska-Lincoln, Association of Public and Land-Grant Universities, and the Association of American Veterinary Medical Colleges. NIAMRRE community connects scientists from a wide range of NIAMRRE member institutions throughout the states, who actively work in AMR addressing five main NC 1206 objectives. The project was established in early 2019, and has provided the following outcomes to date:

- One health certified program – focused on responsible antimicrobial use and audited by the USDA AG marketing service PVP program – was rolled out in early 2020 and offers Turkey and Broiler standards, with Pork standards being released next. Beef, milk, and egg standards are currently under development and expected to be available within the next year. To be certified, participating farms are expected to report entire antimicrobial use and outcomes in an annual basis, along with information used to calculate sustainability metrics. [Objective 3 and 5]

- Development of an online community that connects all member institutions: Kansas State, North Carolina State University, University of Illinois, The Ohio State University, Iowa State University, University of California Davis, University of Florida, University of Iowa, University of Georgia, and University of Nebraska-Lincoln. [Objective 5]

Multi state surveys on perceptions about antibiotic use and resistance in dairy farming. Collaboration between New York, Indiana, California, and Maryland [Objectives 4 and 5]

- Survey results identified that farmers believe that they use antibiotics responsibly, veterinarians expressed that if farmers overuse antibiotics, it is usually because of concerns about animal welfare. Veterinarians also expressed concern about the welfare issues in organic dairy due to the lack of approved treatments. Veterinarians stated that they do not have the necessary tools to properly treat animals in organic dairy farms. [Objective 5]

- Survey of adults indicated that perceptions of antibiotics use have no effect on purchasing decision, and that consumers familiar with Veterinary Feed Directive are more likely to oppose the organic law. [Objective 4]

Manure Management [Objectives 1 - 4]

- Collaboration between Maryland, New York and Pennsylvania quantified antimicrobial resistance in various manure systems across states. On-farm antibiotic degradation study revealed that antibiotic degradation during composting in sick cow bedding can vary between what is reported in the literature, done in laboratory scale, and what happens on farm, likely due to difference in management, time of composting, and temporal conditions. [Objective 1 and 2]
- In a prairie strip manure mitigation study, Iowa State University research demonstrated that water from plots that received manure and received mitigation with prairie strips had decreased antimicrobial resistance gene presence, and a different microbiome when compared to plots that did not receive mitigation, and more similar to plots that did not receive manure application. [Objective 3]
- A four-year collaborative project between Nebraska and Hawaii was initiated in 2017 with support from USDA NIFA, aiming to apply risk-based, systems approach for the identification of critical control points and evaluation of potential intervention strategies to mitigate public health risks imposed by livestock-originated antimicrobial resistance. Beef cattle was investigated as the model system. Multiple interventions implemented on feedlot surface, during manure storage, and at land application were identified and their efficacies was quantified by inactivation of antimicrobial resistant bacteria and genes and reduced human exposure through consumption of fresh produce grown in the field applied with livestock manure. [Objective 2 - 4]

One Health Graduate Online Course [Objective 5]

The University of Maryland, University of Minnesota, North Carolina State University, University of Nebraska-Lincoln, Oklahoma State University, and Washington State University organized and taught an online graduate course. The course was well received and is currently being taught for the second time with five participating universities.

Other accomplishments highlighted:

- A collaboration between Indiana, California, and Minnesota revealed substantial and variable discordance in antimicrobial susceptibility when comparing genotype and phenotype in bacteria isolated from food animals. [Objective 1]
- A new release of the MEGARes database was published, with expanded catalog of biocide and heavy metal resistance genes. [Objective 1]
- A rapid and pen-side detection of antimicrobial resistance genes and pathogens was developed. [Objective 1]
- Discovery of a new compound derived from tomatoes and with antimicrobial activity under low pH. [Objective 3]
- Survey of antimicrobial use in California dairies revealed clusters of antimicrobial use patterns depending on region. [Objective 4]

Funds Leveraging:

- Iowa and California received joint funding to investigate antimicrobial use and stewardship in dairy goats.
- Pennsylvania and New York submitted joint applications to develop and implement a sequencing-based targeted antimicrobial resistance profiling approach.
- Indiana received funding to develop a rapid diagnostic test to investigate antimicrobial resistance patterns in bovine respiratory disease.

Appendix I: Expanded list of accomplishments by objective:

Objective 1. Enhance surveillance and monitoring of antibiotic resistance and develop improved diagnostic tests.

[IA, CA] Improved understanding of the ecology and adaptation of *Campylobacter* on ruminant farms.

[IA, NE] Improved data sharing and data normalization across veterinary diagnostic laboratories.

[MD, MI, NY] Determined the transformations of antibiotics and ARGs in bench-top anaerobic digestion systems and concentrations similar to what is observed in fields, and found that at these low concentrations, the effect on biogas production was minimal, and the effect on antibiotic degradation was inconsistent for tetracycline, but high for sulfamethoxine.

[MD, NY] Quantified on-farm antibiotic residuals and ARGs throughout different on-farm manure management systems, began to understand how different manure treatment processes (solid liquid separation, composting, digestion, lagoon storage) affect AMR. Were able to correlate (or see lack of correlation) between antibiotic administration and antibiotic residuals in the manure management systems.

Objective 2. Determine the ecology and mechanisms involved in resistance and transmission of resistance.

No multi-state activity to report; several single state projects are reported.

Objective 3. Develop and evaluate interventions (including alternatives to antibiotics) that reduce antimicrobial resistance in food production systems.

[IA, KS] Examined the association of fluoroquinolone antibiotic usage with the development of AMR in *Campylobacter* and how the antibiotic treatment influenced the microbiota balance in the intestinal tract.

[IA, TX] Delivered extension training materials on best non-antibiotic treatments for bovine lameness.

Objective 4. Quantify animal health, public health, social, economic, and environmental impacts of antimicrobial interventions in food production systems.

[NY, IN, CA, MD] Improved the understanding of perceptions of dairy farmers, veterinarians and consumers about barriers and motivations to more a judicious antimicrobial use in dairy farming. (*collaboration with Paolo Moroni and Francis Welcome in NY; multistate collaboration with Wendy Beauvais, Robert Schell, David Lansing, Stephanie Lansing).

[NY, MI, NE] A mathematical modeling study to identify new and improved approaches to control antimicrobial resistance (AMR) on heifer raising operations improved our understanding of the effect of management and environmental factors on the dynamics of antibiotic resistance in heifer raising operations and the consumers perceptions of antibiotic use in dairy farming are expected to lead to improved management of AMR.

(*collaboration with Paolo Moroni, Francis Welcome in NY; multistate collaboration with Bo Norby, Bing Wang, Terrance Arthur, John Schmidt, Getahun Agga)

Objective 5. Create and deliver programs on antibiotic stewardship in food production systems through education and outreach.

[MD, NY, NE] iAMResponsible project: In collaboration with Cornell University and University of Nebraska, as well as partners at USDA-ARS, University of Maryland-Baltimore County, and Ithaca College, created video, web, and print information on antimicrobial resistance prevalence, treatment, stewardship, and perceptions. Ithaca College's Park Production will be creating video content, with additional web and print communication materials.

[MD, NE, OR] Facilitated optimal distribution and utilization of AMR-related food safety information and resources at the state, regional and national levels via on-demand access to science-based information, educational resources, and decision-support tools using the iAMResponsible created resources and network.

Appendix II: Publications:

- Abraham ME, Weimer SL, Scoles K, Johnson T, Robison C, Hoverman L, Rocheford E, Rocheford T, Ortiz D, Karcher DM. Orange corn diets associated with lower severity of footpad dermatitis in broilers [under review at Poultry Science] [IN]
- Capps, K. M., R. G. Amachawadi*, M. B. Menegat, J. C. Woodworth, K. Perryman, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, R. D. Goodband, J. Bai, M. D. Apley, B. V. Lubbers, and T. G. Nagaraja. 2020. Impact of added copper, alone or in combination with chlortetracycline, on growth performance, antimicrobial resistance of fecal enterococci of weaned piglets. Journal of Animal Science. 98: skaa003. [KS, IN]
- Craig, A.J., M.L. Soupir, C.R. Rehmann. (in press). Sectional Model of a Prairie Buffer Strip in a Laboratory Flume for Water Quality Research. *Agrosystems, Geosciences & Environment.* [IA]
- Dai, L., O. Sahin, M. Grover, Q. Zhang. 2020. New and alternative strategies for the prevention, control, and treatment of antibiotic-resistant *Campylobacter*. Transl. Res. S1931-5244(20)30072-4. doi: 10.1016/j.trsl.2020.04.009. [IA, MN]
- Enakshy Dutta, J. Dustin Loy, Caitlyn A. Deal, Emily L. Wynn, Michael L. Clawson, Jennifer Clarke, Bing Wang. 2021. Development of a multiplex real-time PCR assay for predicting macrolide and tetracycline resistance associated with bacterial pathogens of bovine respiratory disease. Pathogens. 10(1), 64. https://doi.org/10.3390/pathogens10010064. [NE]
- Gaeta, N.C., E. Bean, A.M. Miles, D.U.O.G. de Carvalho, M.A.R. Alemán, J.S. Carvalho, L. Gregory, and E. Ganda. 2020. A Cross-Sectional Study of Dairy Cattle Metagenomes Reveals Increased Antimicrobial Resistance in Animals Farmed in a Heavy Metal Contaminated Environment. Front. Microbiol. 11:2801. doi:10.3389/fmicb.2020.590325. [PA, Brazil]
- Hurst, J.J., Oliver, J., Schueler, J., Gooch, C.A., Lansing, S., Crossette, E., Wiggington, K.R., Raskin, L., Aga, D.S., Sassoubre, L.M., 2019. Trends in antimicrobial resistance genes in manure blend pits and long-term storage across dairy farms with comparisons to antimicrobial usage and residual concentrations. Environmental Science & Technology 53(5): 2405-2415. doi: 10.1021/acs.est.8b05702. [NY, MD, MI]
- Johnson TA, Sylte MJ, Looft T. 2019. In-feed bacitracin methylene disalicylate modulates the turkey microbiota and metabolome in a dose-dependent manner. Sci Rep 9:8212 http://doi.org/10.1038/s41598-019-44338-5 [IA, IN]
- Kuralayanapalya, S. P., S. S. Patil, S. Hamsapriya, R. Shinduja, P. Roy, and R. G. Amachawadi*. 2019. Prevalence of extended-spectrum beta-lactamase producing bacteria from animal origin: A systematic review and meta-analysis report from India. PLoS One. 14 (9): e0221771. [IA]
- Liu, M., Y. Zhao, H. Monshat, Z. Tang, Z. Wu, Q. Zhang, M. Lu. 2020. An IoT-enabled paper sensor platform for real-time analysis of isothermal nucleic acid amplification tests. Biosens Bioelectron 169:112651. doi: 10.1016/j.bios.2020.112651.

- Llanos-Soto, S., N. Vezeau, M. Wemette, E. Bulut, A. Greiner Safi, P. Moroni, M.A. Shapiro, R. Ivanek. Survey of perceptions and attitudes of an international group of veterinarians regarding antibiotic use and resistance on dairy cattle farms. Preventive Veterinary Medicine. Preventive Veterinary Medicine (In press). [NY, Italy]
- Maria C. Hall, Jon Duerschner, John Gilley, Amy Schmidt, Shannon Bartelt-Hunt, Daniel Snow, Kent Eskridge, and Xu Li. 2020. Antibiotic resistance genes in swine manure slurry as affected by pit additives and facility disinfectants. Science of the Total Environment, in press. [NE]
- Maria Cecilia Hall, Noelle A. Mware, John E. Gilley, Shannon Bartelt-Hunt, Daniel D. Snow, Amy M. Schmidt, Kent M. Eskridge, and Xu Li. 2020. Influence of setback distance on antibiotics and antibiotic resistance genes in runoff and soil following the land application of swine manure slurry. Environmental Science and Technology, 54 (8): 4800-4809. [NE]
- Martin, M.S., Kleinhenz, M. D., Kleinhenz, K., Reppert, E., Blasi, D., Parks, T., Baysinger, A., Hutcheson, J., Coetzee, J.F. 2020. Comparison of the effect of tildipirosin administered alone or in combination with transdermal flunixin on the performance, health, activity, and well-being of transported feedlot calves on arrival at the feedlot, *Translational Animal Science*, 4 (1): 452–459. https://doi.org/10.1093/tas/txaa005 [KS, NJ]
- Monshat H., Z. Wu, J. Pang, Q. Zhang, M. Lu. 2020. Integration of plasmonic heating and on-chip temperature sensor for nucleic acid amplification assays. J. Biophotonics: e202000060. [IA]
- Mou, K. T, Allen, H. K, Alt, D. P, Trachsel, J., Hau, S. J, Coetzee, J. F, Holman, D. B, Kellner, S., Loving, C. L, & Brockmeier, S. L. 2019. Shifts in the nasal microbiota of swine in response to different dosing regimens of oxytetracycline administration. *Veterinary microbiology*, 237: 108386. doi: 10.1016/j.vetmic.2019.108386 [TN, IA, KS, Canada]
- Muurinen J, Richert J, Wickware CL, Richert B, Johnson TA. Swine growth promotion with antibiotics or alternatives increases antibiotic resistance gene mobility potential in the fecal microbiome [under review at Scientific Reports] [IN, KS]
- Neher, T., L. Ma, T.B. Moorman, A.C. Howe, M.L. Soupir. 2020. Catchment-scale export of antibiotic resistance genes and bacteria from an agricultural watershed in central Iowa. *PLoS one*. 15(1): e0227136. DOI: https://doi.org/10.1371/journal.pone.0227136 [IA]
- Neher, T., L. Ma, T.B. Moorman, A.C. Howe, M.L. Soupir. 2020. Seasonal variations in export of antibiotic resistance genes and bacteria in runoff from a small-scale agricultural watershed in central Iowa. *Science of the Total Environment.* 140224 DOI: https://doi.org/10.1016/j.scitotenv.2020.140224 [IA]
- Oliver, J., Gooch, C., Lansing, S., Schueler, J., Hurst, J., Sassoubre, L., Crossette, E., Aga, D., 2020. Invited Review: Fate of antibiotic residues, antibiotic-resistant bacteria, and antibiotic resistance genes in US dairy manure management systems. Journal of Dairy Science 103:1051-1071. doi: 10.3168/jds.2019-16778. [CO, IA, GA, Germany]
- Paudyal S, Manriquez D, Velasquez A, Shearer JK, Plummer PJ, Melendez P, Callan RJ, Sorge US, Bothe H, Velez J, Pinedo PJ. Efficacy of non-antibiotic treatment options for digital dermatitis on an organic dairy farm. The Veterinary Journal. 2020 Jan 1;255:105417.

- Rachel E. Levine, Yuping Zhang, Yifei Leng, Daniel D. Snow, David Cassada, Lisa M. Durso, and Xu Li. 2019. Microbial transformation of a sulfonamide antibiotic under various background nutrient conditions. Bulletin of Environmental Contamination and Toxicology, 103(6): 808-813. [NE, DC]
- Redding LE, Brooks C, Georgakakos CB, Habing G, Rosenkrantz L, Dahlstrom M, Plummer PJ. Addressing Individual Values to Impact Prudent Antimicrobial Prescribing in Animal Agriculture. Front Vet Sci. 2020 May 28;7:297. doi: 10.3389/fvets.2020.00297. PMID: 32548132; PMCID: PMC7270172.[PA, MS, OH, IA, Canada]
- Renys Barrios, Himanshu Khuntia, Shannon Bartelt-Hunt, John Gilley, Amy Schmidt, Daniel Snow, and Xu Li. 2020. Fate and transport of antibiotics and antibiotic resistance genes in runoff and soil as affected by the timing of swine manure slurry application. Science of the Total Environment, 712: 136505. [NE]
- Reppert, E.J., Reif, K.E., Montgomery, S.R., Magnin, G., Zhang, Y., Martin-Jimenez, T., Olson, K.C., Coetzee, J.F. 2020. Determination of plasma chlortetracycline (CTC) concentrations in grazing beef cattle fed one of four FDA approved free-choice CTC medicated minerals, *Translational Animal Science*. 4 (2): 1128 – 1133. https://doi.org/10.1093/tas/txaa048. [KS, TN]
- Ricker, N., Trachsel, J., Colgan, P., Jones, J., Choi, J., Lee, J., Coetzee, J.F., Howe, A., Brockmeier, S.L., Loving, C.L., Allen, H.K. 2020. Toward antibiotic stewardship: Route of antibiotic administration impacts the microbiota and resistance gene diversity in swine feces. *Front. Vet. Sci*. Vol. 7 Article 255. https://doi.org/10.3389/fvets.2020.00255 [IA, KS]
- Schueler, J., Lansing, S., Crossette, E., Nass, J., Hurst, J., Raskin, L., Wigginton, K., Aga, D., Accepted with revisions. Tetracycline, Sulfadimethoxine, and Antibiotic Resistance Gene Dynamics during Anaerobic Digestion of Dairy Manure. Journal of Environmental Quality. [NY, MD]
- Šimunović K, O. Sahin, J. Kovač, J. Shen, A. Klančnik, Q. Zhang, et al. 2020. (-)-α-Pinene reduces quorum sensing and Campylobacter jejuni colonization in broiler chickens. PLoS ONE 15(4): e0230423. https://doi.org/10.1371/journal.pone.0230423. [IA, PA, Slovenia]
- Smith JS, Kreuder AJ, Dowling PM, Dohlman TM, Plummer PJ, Toutain PL, Mochel JP. Re:"Evaluation of Enrofloxacin for Use in Cryopreservation of Zebu Bull (Bos indicus) Semen" by Ishaq et al.(Biopreserv Biobank 2019; 17 (6): 546–552, DOI: 10.1089/bio. 2018.0133). Biopreservation and Biobanking. 2020 Feb 1;18(1):41-2. [IA, Canada]
- Van Bibber-Krueger, C. L., C. I. Vahl, S. K. Narayanan, R. G. Amachawadi, E. A. Taylor, H. M. Scott, and J. S. Drouillard. 2019. Effects of supplemental zinc sulfate on growth performance, carcass characteristics, and antimicrobial resistance in feedlot heifers. Journal of Animal Science. 97:424-436. doi:10.1093/jas/sky411. [IA]
- Wemette M., A. Greiner Safi, W. Beauvais, K. Ceres, M. Shapiro, P. Moroni, F. L. Welcome, R. Ivanek. 2020. New York State Dairy Farmers' Perceptions of Antibiotic Use and Resistance: A Qualitative Interview Study, PLOS ONE 15(5): e0232937. https://doi.org/10.1371/ [NY]

- Wemette, M., Greiner Safi, A., Wolverton, A.K., Beauvais, W., Shapiro, M., Moroni, P., Welcome, F., Ivanek, R. Public Perceptions of Antibiotic Use on Dairy Farms in the United States. Journal of Dairy Science. 2020 (In press) [NY]
- Wu Z, Yaeger MJ, Sahin O, Xu C, Beyi AF, Plummer PJ, Meral Ocal M, Zhang Q. A Homologous Bacterin Protects Sheep against Abortion Induced by a Hypervirulent *Campylobacter jejuni* Clone. Vaccines (Basel). 2020 Nov 6;8(4):662. doi: 10.3390/vaccines8040662 [IA]
- Wu, F., M. D. Tokach, J. M. DeRouchey, S. S. Dritz, J. C. Woodworth, R. D. Goodband, K. Chitakasempornkul, N. M. Bello, K. Capps, S. Remfry, H. M. Scott, T. G. Nagaraja, M. D. Apley, and R. G. Amachawadi*. 2019. Effects of tylosin administration routes on the prevalence of antimicrobial resistance among fecal enterococci of finishing swine. Foodborne Pathogens and Disease. 16:309-316. doi:10.1089/fpd.2018.2551. [KA, TX]
- Yaeger, M.J., Z. Wu, P.J. Plummer, O. Sahin, M.M. Ocal, A. Beyi, C. Xu, Q. Zhang. R. Griffith. 2020. Experimental evaluation of Tulathromycin as a treatment for Campylobacter jejuni abortion in pregnant ewes. AJVR. 81: 205-209. [IA]
- Yangjunna Zhang, John W. Schmidt, Terrance M. Arthur, Tommy L. Wheeler, Bing Wang. A comparative quantitative assessment of human exposure to various antimicrobial-resistant bacteria among U.S. ground beef consumers. Journal of Food Protection. Accepted in 2020. https://doi.org/10.4315/JFP-20-154 [NE]
- Yarlagadda V, Medina R, Johnson TA, Koteva KP, Cox G, Thaker MN, & Wright GD (2020). Resistance-Guided Discovery of Elfamycin Antibiotic Producers with Antigonococcal Activity. *ACS Infectious Diseases*, http://doi.org/10.1021/acsinfecdis.0c00467 [in press] [IN, MA, Canada]
- Zach R. Staley, Christopher Y. Tuan, Kent M. Eskridge, and Xu Li. 2020. Using the heat generated from electrically conductive concrete slabs to reduce antibiotic resistance in beef cattle manure. Science of the Total Environment, accepted. [NE]
- Zachary R. Staley, Amy Millmier Schmidt, Bryan Woodbury, Kent M. Eskridge, Lisa Durso, and Xu Li. 2019. Corn stalk residue may add antibiotic resistant bacteria to manure composting piles. Journal Environmental Quality, 49 (3): 745-753. [NE]

Appendix III: Scientific and Outreach Presentations:

- Amachawadi, R. G,, S. E. Remfry, X. Shi, L. Feuerbacher, J. Bai, M. D. Tokach, S. S. Dritz, R. D. Goodband, J. M. DeRouchey, J. C. Woodworth, and T. G. Nagaraja. 2019. Fecal prevalence of the top-7 Shiga toxin-producing *Escherichia coli* in finisher pigs. 100th Annual Proceedings of Conference of Research Workers in Animal Diseases, November 2-5, Chicago, Illinois. Oral presentation.
- Atobatele, M., S. E. Remfry, Y. Romero, X. Shi, R. Phebus, R. G. Amachawadi, and T. G. Nagaraja. 2019. Detection, isolation, and antimicrobial susceptibility testing of *Salmonella enterica* from wheat grain samples. BugAPalooza, public health event hosted in Manhattan City Park, April 1st, Manhattan, Kansas, USA.
- Atobatele, M., S. E. Remfry, Y. Romero, X. Shi, R. Phebus, R. G. Amachawadi, and T. G. Nagaraja. 2019. Detection, isolation, and antimicrobial susceptibility testing of *Salmonella enterica* from wheat grain samples. Proceedings of the Annual Phi-Zeta Research Day of College of Veterinary Medicine, March 26, Kansas State University, Manhattan, Kansas, USA.
- Beyi, A.F., T.J. Hawbecker, C. Slagel, B. Ruddell, A. Hassall, R. Dewell, G. Dewell, O. Sahin, Q. Zhang, P.J. Plummer. 2019. Alterations of Gut Microbiota Following Treatment of Bovine Respiratory Disease with Danofloxacin in Beef Calves. Conference of Research Worker in Animal Diseases. Nov.2-5, 2019, Chicago, IL, USA.
- Bowcutt, B., K. Vasco, S. Carbonell, R. Mosci, L. Zhang, S.D. Manning. Quantification and characterization of third- generation cephalosporin resistant bacteria recovered from Michigan dairy cattle. Submitted to the University Undergraduate Research and Arts Forum (UURAF) at MSU. 2020.
- Bulut, E., Ivanek, R. Comparison of different biomass methodologies to adjust sales data on veterinary antimicrobials in the US. 2020 Conference for Research Workers in Animal Agriculture (CRWAD) Virtual Conference, December 5-8, 2020. Oral presentation.
- Bulut, E., Stout, A., Wemette, M., Llanos-Soto, S., Schell, R., Greiner Safi, A., Shapiro, M., Moroni, P., Ivanek, R. How does public perception of antibiotic use on dairy farms contribute to purchasing organic? 2020 Conference for Research Workers in Animal Agriculture (CRWAD) Virtual Conference, December 5-8, 2020. Oral presentation.
- Chastain C, Richert BT, Schinckel AP, Johnson TA, Wickware CL, Thayer M, Mills KM, Feldpausch J, Palencia JP, and Radcliffe JS. 2019. Effects of feeding soluble fiber (dextrin) to pigs pre- and post-weaning on growth performance and volatile fatty acid (VFA) production. Midwest Swine Nutrition Conference. Omaha, NE. [Johnson lab contributed to experimental design, animal
- Coetzee, J.F., Magstadt, D., Follett, L., Sidhu, P., Schuler, A.. Krull, A., Cooper, V., Engelken, T. O'Connor, A M. 2019. Association between antimicrobial class for retreatment of BRD and frequency of resistant BRD pathogen isolation. Abstract 136. Conference of Research Workers in Animal Diseases. Session 28, November 4, 2019. Available at https://crwad.org/wp-content/uploads/2019/10/CRWAD-2019-Author-Index-and-Abstracts.FINAL_.pdf

- Ece Bulut, Darshan Baral, Xu Li, Galen E. Erickson, Amy M. Schmidt, John W. Schmidt, Bing Wang. Fate of antimicrobial resistance in the environment: From beef cattle production through manure storage and land application. Oral presentation at International Association of Food Protection 2019 annual meeting. Louisville, KY. July 21 - 24, 2019.
- Enakshy Dutta, Dustin Loy, Caitlyn A. Deal, Jennifer Clarke, Bing Wang. Development of a multiplex real-time PCR assay for detection of major antimicrobial resistant bacterial pathogens associated with bovine respiratory disease complex from clinical samples. iPoster presentation at PIRI AMR Consortium virtual poster event. May 26 - 29, 2020.
- Enakshy Dutta, Ece Bulut, Xu Li, Amy Schmidt, Galen Ericksen, Jennifer Clarke, Bing Wang. Inactivation of antimicrobial resistant bacteria during manure storage as static stockpiles. Accepted as poster presentation at IAFP 2020 Annual Meeting. Virtual event. October 26 - 28, 2020.
- Enakshy Dutta, Ece Bulut, Xu Li, Amy Schmidt, Galen Ericksen, Jennifer Clarke, Bing Wang. Inactivation of antimicrobial resistant bacteria during manure storage as static stockpiles. iPoster presentation at PIRI AMR Consortium virtual poster event. May 26 - 29, 2020.
- Garcia, C., K. Vasco, S. Wengert, S.D. Manning. The role that intramammary ceftiofur has on the resistant bacterial populations in the gut of dairy cattle. National Veterinary Scholar Symposium. Boston, MA. 2019
- Goulart, D., A. Beyi, S. Wilson, R. Dewell, G. Dewell, P. Plummer, M. Ocal, Z. Wu, K. Singh, L. Dai, C. Xu, J. Xia, B. Ruddell, Q. Zhang, and O. Sahin. Effect of danofloxacin treatment on the development of fluoroquinolone resistance in *Campylobacter jejuni* in cattle. Oral presentation at Conference of Research Workers in Animal Diseases (CRWAD) Meeting, November 2-5, 2019, Chicago, IL.
- Habib, K., R. G. Amachawadi, V. Ishengoma, X. Shi, T. Mahmood, W. M. Hutchens, M. D. Tokach, S. S. Dritz, J. C. Woodworth, R. D. Goodband, J. M. DeRouchey, and T. G. Nagaraja. 2020. Effects of in-feed vs. in-water antibiotic administration on antimicrobial resistance of fecal *Escherichia coli* in piglets. 2020 Midwest American Society of Animal Science meeting, March 2-4, Omaha, NE. Oral presentation.
- Hancock, S., R. G. Amachawadi, G. Baca, S. Sexton-Bowser, D. Smolensky, D. Rhodes, T. Herald, J. S. Drouillard, D. U. Thomson, and T. G. Nagaraja. 2019. Evaluation of the antimicrobial activities of sorghum phenolic compounds. Proceedings of the Annual Phi-Zeta Research Day of College of Veterinary Medicine, March 26, Kansas State University, Manhattan, Kansas, USA.
- Hutchens, W. M., M. D. Tokach, S. S. Dritz, J. C. Woodworth, J. M. DeRouchey, R. D. Goodband, H. I. Calderon-Cartagena, K. Habib, V. Ishengoma, T. G. Nagaraja, and R. G. Amachawadi. 2020. Evaluating the route of antibiotic administration and its effect on nursery pig growth performance. 2020 Midwest American Society of Animal Science meeting, March 2-4, Omaha, NE. Oral presentation.
- Ishengoma, V., R. G. Amachawadi, K. Habib, X. Shi, T. Mahmood, W. M. Hutchens, M. D. Tokach, S. S. Dritz, J. C. Woodworth, R. D. Goodband, J. M. DeRouchey, and T. G. Nagaraja. 2020. Impact of in-feed vs. in-water antibiotic administration on the fecal

prevalence and antimicrobial susceptibilities of *Campylobacter* and *Salmonella* in piglets. 2020 Midwest American Society of Animal Science meeting, March 2-4, Omaha, NE. Oral presentation.

- Kaniyamattam K., LW Tauer, and YT Grohn. The economic costs of antibiotic use constraints in U.S. integrated beef supply chains: A systems approach. The Conference of Research Workers in Animal Diseases (CRWAD). December 5-8, 2020.
- Lansing, S., 2019. Anaerobic digestion of manure, algae, food waste, and wastewater for energy production, nutrient transformations, and reduction of antimicrobial resistance. John Hopkins School of Public Health Wolman Seminar. Baltimore, MD. April 9, 2019.
- Lansing, S., Cottrell, C., Sharif, R., 2019. Antimicrobial resistance. University of Maryland Health Center: Student Health Advisory Committee. College Park, MD. November 20, 2019.
- Lansing, S., Schueler, J., Crossette, E., Naas, K., Hurst, J., Oliver, J., Raskin, L., Wiggington, K. Gooch, C., Aga, D., 2019. Fate of antimicrobials during dairy manure management and processing. Waste to Worth Conference. Minneapolis, MN. April 24-26, 2019.
- Lansing, S., Schueler, J., Crossette, E., Naas, K., Hurst, J., Oliver, J., Raskin, L., Wiggington, K. Gooch, C., Aga, D., 2019. Effect of microbial treatment processes on antimicrobial resistance (AMR): Digestion and composting. American Ecological Engineering Society. Asheville, NC. June 3-6, 2019.
- Lansing, S., Schueler, J., Crossette, E., Naas, K., Hurst, J., Oliver, J., Raskin, L., Wiggington, K. Gooch, C., Aga, D., 2019. Fate of antimicrobials during dairy manure management and processing. Waste to Worth Conference. Minneapolis, MN. April 24-26, 2019.
- Lansing, S., Schueler, J., Crossette, E., Naas, K., Hurst, J., Oliver, J., Raskin, L., Wiggington, K. Gooch, C., Aga, D., 2019. Effect of microbial treatment processes on antimicrobial resistance (AMR): Digestion and composting. American Ecological Engineering Society. Asheville, NC. June 3-6, 2019.
- Llanos-Soto, S., Vezeau, N., Wemette, M., Bulut, E., Greiner Safi, A., Moroni, P., Shapiro, M.A., Ivanek, R. International survey of veterinarians' perceptions about antibiotic use and resistance on dairy cattle farms. 2020 Conference for Research Workers in Animal Agriculture (CRWAD) Virtual Conference, December 5-8, 2020. Oral presentation.
- M. Cecilia Hall, Noelle Mware, John Gilley, Shannon Bartelt-Hunt, Daniel Snow, Yusong Li, and Xu Li. 2019. Determining the setback distance needed to minimize the transport of antibiotics and antibiotic resistance genes in runoff following the land application of swine manure slurry. American Society for Microbiology, San Francisco, CA, Jun 20-24.
- M. Cecilia Hall, Noelle Mware, John Gilley, Shannon Bartelt-Hunt, Daniel Snow, Yusong Li, and Xu Li. 2019. Determining the setback distance needed to minimize the transport of antibiotics and antibiotic resistance genes in runoff following the land application of swine manure slurry. 5th International Symposium on the Environmental Dimension of Antibiotic Resistance, Hong Kong, China, Jun 9-14.

- Magossi, G., R. G. Amachawadi, T. G. Nagaraja, D. Kelly, B. Ge, S. Young, and V. Trinetta. 2020. Whole-genome sequencing and phenotypic susceptibilities of antimicrobial and heavy metal susceptibilities of *Salmonella* spp. and *Escherichia coli* isolates from U. S. Swine feed mills. 2020 IAFP Annual meeting, August 2-5, Cleveland, Ohio. Oral presentation.
- Mara Zelt, Amy M. Schmidt, Zachary Staley, Xu Li, Bing Wang, Dan Miller. Antibiotic resistance profiles in fallow soil receiving raw, composted or stockpiled beef manure, or inorganic fertilizer. Accepted as poster presentation at the 6th World Once Health Congress (virtual event). October 30 - November 3, 2020.
- Mohammadreza Shafieifini and Xu Li. 2019. The effects of nutrient level and growth rate on conjugation frequency of antibiotic resistance genes in water. AEESP meeting, Tempe, AZ, May 14-16.
- Muurinen J (2019) Antibiotic resistance in agriculture. Annual Veterinary Congress, Helsinki, Finland. [invited speaker]
- Muurinen J, Richert J, Richert B, Johnson TA (2019) Will antibiotic-alternative growth promoters reduce antibiotic resistance in the microbiome? 8th Symposium on Antimicrobial Resistance in Animals and the Environment, Tours, France.
- Muurinen J, Richert J, Richert B, Johnson TA (2019) Will antibiotic-alternative growth promoters reduce antibiotic resistance in the microbiome? Purdue Microbiome Symposium, West Lafayette, IN
- Muurinen J, Richert J, Richert B, Johnson TA (2019) Will antibiotic-alternative growth promoters reduce antibiotic resistance in the microbiome? Indiana Branch American Society of Microbiology Meeting, Nashville, IN.
- Muurinen J. (2019) Antibiotic resistance in Finnish agroecosystems. Environmental dimension of antimicrobial resistance in China and Finland [invited speaker].
- Neher, T.P., M.L. Soupir, D.S. Anderson, A.C. Howe. 2020. Evaluation of manure associated antibiotic resistance genes from multiple swine and cattle feedlots for improved antimicrobial resistance monitoring in agriculture. Presented at the Virtual ASABE AIM, 7/12/20 to 7/15/20.
- Noelle Mware, Marissa Golgosky, Amy Schmidt, and Xu Li. 2019. The effectiveness of alkaline stabilization on the reduction of antibiotic resistance in beef cattle manure. AEESP meeting, Tempe, AZ, May 14-16.
- Poindexter, C., Lansing, S., 2019. Anaerobic digestion policy analysis: Understanding perceptions, knowledge, and implementation. Waste to Worth Conference. Minneapolis, MN. April 24-26, 2019.
- Remfry, S. E., R. G. Amachawadi, X. Shi, L. Feuerbacher, J. Bai, M. D. Tokach, S. S. Dritz, R. D. Goodband, J. M. DeRouchey, J. C. Woodworth, and T. G. Nagaraja. 2019. Shiga toxin-producing *Escherichia coli* in Swine: Prevalence, Serogroups, and Public Health Implications. Texas A&M University Graduate Student Association Meeting, April 22nd, College of Veterinary Medicine, Texas A&M University, College Station, Texas, USA.

- Remfry, S. E., R. G. Amachawadi, X. Shi, L. Feuerbacher, J. Bai, M. D. Tokach, S. S. Dritz, R. D. Goodband, J. M. DeRouchey, J. C. Woodworth, and T. G. Nagaraja. 2019. Shiga toxin-producing *Escherichia coli* in commercial finisher pig feces. Proceedings of the Annual Phi-Zeta Research Day of College of Veterinary Medicine, March 26, Kansas State University, Manhattan, Kansas, USA.
- Renys Barrios, Shannon Bartelt-Hunt, and Xu Li. 2019. Influence of manure application on the resistome in the subsurface soil. AEESP meeting, Tempe, AZ, May 14-16.
- Rocha, F.I., M.L. Soupir, T.B. Moorman, A.C. Howe. 2020. Effect of manure application on bacterial community in soil layers and leachate from varying management histories. Online Ecological Society of America Conference.
- Sarwar, F., J. S. Suchodolski, R. G. Amachawadi, J. S. Drouillard, J. Vinasco, T. G. Nagaraja, K. N. Norman, G. H. Loneragan, and H. M. Scott. 2019. Changes in fecal microbiota of cattle fed the beta-adrenergic agonist ractopamine hydrochloride and elevated zinc. 100th Annual Proceedings of Conference of Research Workers in Animal Diseases, November 2-5, Chicago, Illinois. Oral presentation.
- Sarwar. F., J. S. Suchodolski, R. G. Amachawadi, J. S. Drouillard, J. Vinasco, T. G. Nagaraja, K. N. Norman, G. H. Loneragan, and H. M. Scott. 2020. Changes in fecal microbiota of cattle fed the beta-adrenergic agonist Ractopamine hydrochloride. 16th January 2020. The College of Veterinary Medicine Spring Symposium, Texas A&M University, College Station, TX. Poster presentation.
- Vargas JIV, Consoli O, Rocheford E, Hoverman L, Rocheford T, Karcher D, Johnson TA. (2019) Evaluation of a high carotenoid corn diet as modulator of the chicken gut microbiome. Purdue Undergraduate Research Symposium.
- Vasco, K., S. Carbonell, R. Mosci, B. Bowcutt, R. Erskine, L. Sordillo-Gandy, B. Norby, P. Ruegg, L. Zhang, S.D. Manning. Variation in intestinal antibiotic-resistant bacterial populations in dairy cattle following a third-generation cephalosporin treatment. 2020. Submitted to ASM Microbe.
- Wickware C, Chastain C, Radcliffe JS, Schinkel AP, Richert B, Johnson TA. (2019) Effects of feeding soluble fiber (dextrin) to pigs pre- and post-weaning on the gut bacterial community. Poster presented at Inaugural Purdue Applied Microbiome Sciences Symposium, West Lafayette, IN.
- Yangjunna Zhang, Ece Bulut, Xu Li, Amy Schmidt, John W. Schmidt, Terrance M. Arthur, Bing Wang. Impact of livestock production systems on human exposure to β-lactam resistant Escherichia coli through consumption: Quantitative microbial exposure assessment. iPoster presentation at PIRI AMR Consortium virtual poster event. May 26 - 29, 2020.
- Yangjunna Zhang, Terrance M. Arthur, John W. Schmidt, Tommy L. Wheeler, Bing Wang. A comparative quantitative assessment of human exposure risks to various antimicrobial resistant bacteria among U.S. ground beef consumers. Oral presentation at Society for Risk Analysis 2019 annual meeting. Arlington, VA. December 8 - 12, 2019 (T4-F5. Using QMRA to Inform Risk Management Decisions).

- Yarberry, A., Poindexter, C., Rice, C., Lansing, S., 2019. Antibiotic measurement and recovery in manure and impacts on antimicrobial resistance in agricultural settings. Waste to Worth Conference. Minneapolis, MN. April 24-26, 2019.
- Yarberry, A., Rice, C., Poindexter, C., Lansing, S. 2019. Use of triple quadrupole mass spectrometry to characterize antibiotics in cow manure. 67th American Society for Mass Spectrometry Conference, Atlanta, GA. June 2-6, 2019.