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# Journal of Swine Health & Production

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*The Journal of the American Association of Swine Veterinarians*

# *Journal of Swine Health and Production*

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A young Hampshire pig in a Missouri barn

*Photo courtesy of Tina Smith*

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*quoted from the Executive Editor's message, page 105*

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# Be careful what we ask for

As we have been working through the implementation of the new Veterinary Feed Directive (VFD) rules, there is lot we have learned. The implementation of these new rules has not turned out as badly as we expected, but most certainly, many questions have come up. We were fortunate to have had previous experience with VFDs. Even so, because we all want to follow the rules, many questions have arisen on how to address some specific situations. The initial response is that the VFD rules need to have very clear and specific answers to all our questions. Although this might seem like a good option, we must be very careful of what we ask for.

The challenge becomes that, as we ask for clarification on a specific issue, we force commitment to the specific answer. Although it may seem like a good answer at the time, it is likely to constrain our options on future situations that may vary slightly. The more specific rules become, the more black and white they may appear, but the more they may limit our practice of veterinary medicine. We may think of this as comparable to any diagnostic assay. All assays have a diagnostic sensitivity and specificity. Diagnostic sensitivity is defined as the ability to correctly identify all positive samples from a group of known positives (high diagnostic sensitivity = small number of false negatives). Diagnostic specificity is defined as the ability to correctly identify all negative samples from a group of known negatives (high specificity = small number of false positives). Generally, the more we improve the diagnostic sensitivity of an assay, the more likely it is to have false positives (lower specificity). The opposite is also true: as an assay's diagnostic specificity improves, the more likely it is to have false negatives (lower sensitivity).

*"The more specific rules become, the more black and white they may appear, but the more they may limit our practice of veterinary medicine."*

So in the case of the new VFD regulations, the more specific the rule becomes (ie, the more it clarifies each specific situation) the more likely it is that slight deviations of the scenario will be considered illegal, even though we would all agree that clinically, these scenarios are exactly the same. This situation is comparable to a polymerase chain reaction (PCR) test, in that the more nucleotides we add to the primer, the more specific it becomes, and the more likely that we will miss a slight variation of the pathogen (lower sensitivity). As field veterinarians, we look at a multitude of different pieces of clinical information (history, signalment, clinical signs, diagnostic results, etc) to make decisions. Sometimes we rely on culture of the organism, a PCR, or histologic changes to confirm the etiologic diagnosis. Sometimes our diagnosis is made in one group of pigs, and on the basis of epidemiological testing and pathogenesis, it applies to other pigs in the same flow. That is the science and practice of veterinary medicine. That is something we want to keep at our discretion rather than allow any regulatory agency to dictate to us.

Yes, many things in life are not black and white. In school, many times we have to make things simple to make them seem black and white so they can be graded. So, although ambiguity creates uncertainty (some areas of gray), we must be careful of what we ask for. There is no doubt we will be seeing more and more regulation of our clinical decision-making, especially regarding antimicrobial use. We are all behind judicious use of antimicrobials. We must continue to be proactive in ensuring these new regulations do not affect our ability to treat pigs in a timely manner, so we can protect our pigs' health and welfare and prevent and relieve pig suffering, while still maintaining the utmost in safe food and protecting public health. All of these are critical parts of our veterinary oath.

Alex Ramirez, DVM
AASV President

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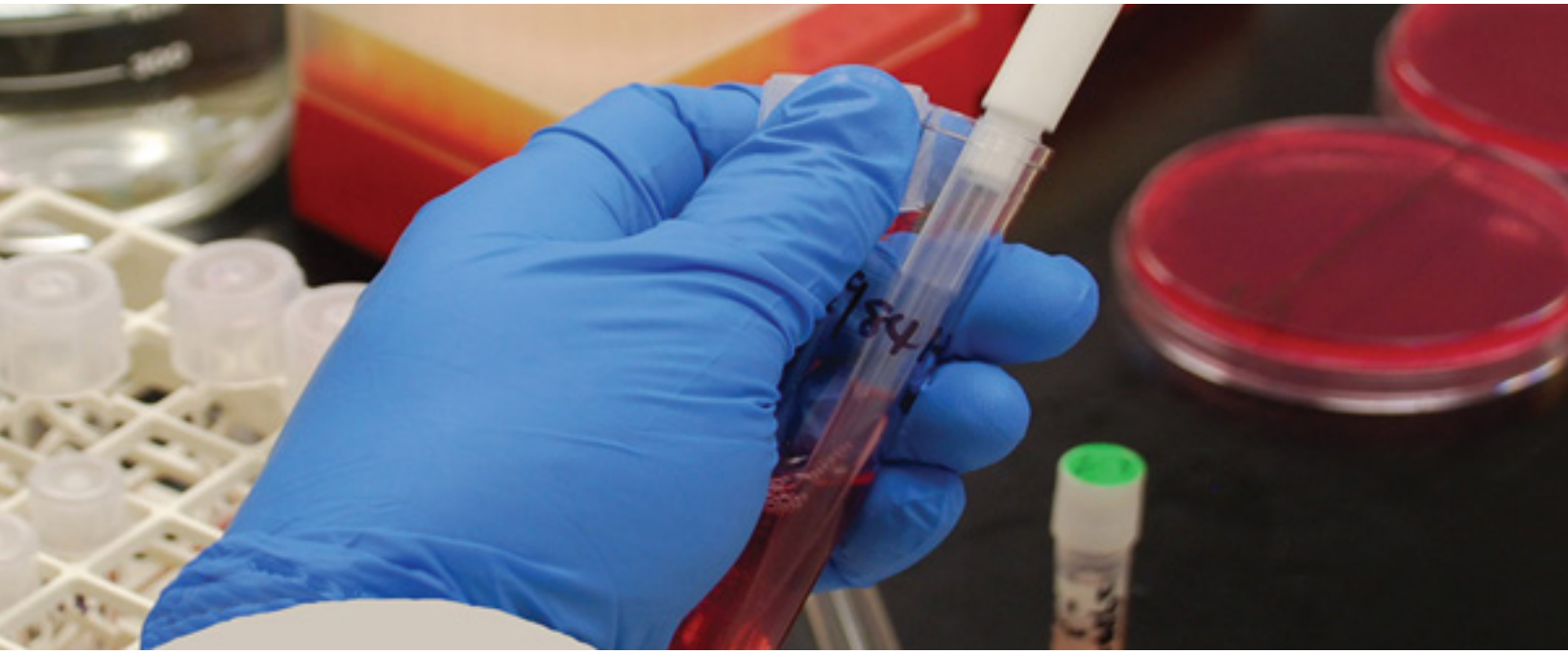

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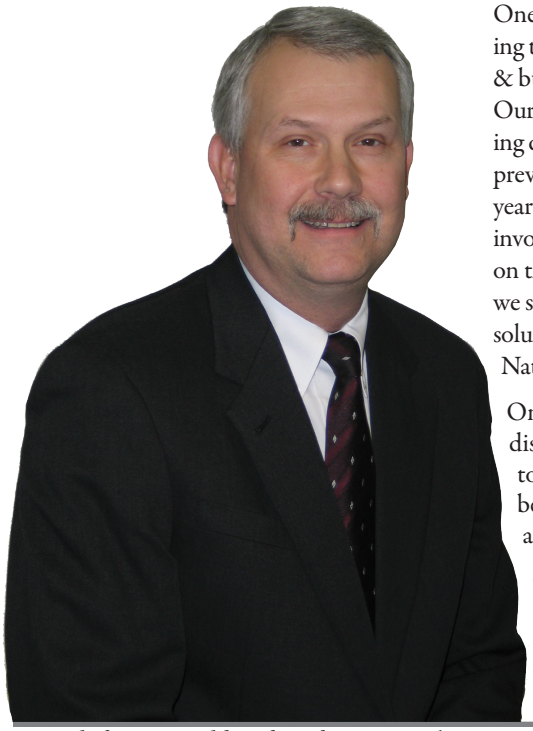
# Full value: AASV Annual Meeting

The 2017 AASV Annual Meeting has now come and gone. A great crowd was gathered in Denver for the full value of educational, social, collegial, and professional benefits gained from interacting with swine veterinarians from around the world. Kudos go to Dr Alex Ramirez and his committee for an outstanding program. For me, the annual meeting is a great time to catch up with a large number of friends and colleagues. It is also time to catch a glimpse at the issues confronting our members.

Certainly "antibiotics" is top-of-mind as veterinarians adjust to the new regulations on Veterinary Feed Directives (VFDs) and prescriptions for water-based antibiotics. It seems that this transition has gone as well as it possibly could go. Swine veterinarians and pork producers spent valuable time in 2016 getting prepared for the changes. I did hear comments about the volume of VFDs being written, as well as some frustration with the need for more definitive answers to questions being posed to the US Food and Drug Administration. It is important to remember that this is a work in progress and that all involved will get better at it with time (including the regulators). The important things to remember are still the science and documentation of the right diagnosis, drug, dosage, route of administration, duration, and withdrawal.



*"Setting aside our differences, biases, preconceived ideas, and proprietary interests will enable an effort resulting in action towards the shared goal of beating PRRS."*

Another aspect of antibiotic use is not using antibiotics. The seminar entitled "Antibiotic-free pork production" was very well attended. This demonstrated the interest of our members in this production niche and the pigs involved. There are also a number of commercial companies bringing products and technologies into the market. The jury is still out on where consumer demand will ultimately take this niche, but it is vital for veterinarians to be involved in the decisions that affect the pigs' health and welfare. A demonstration of this involvement is the progress made by several veterinarians in decreasing the need for antibiotics in the finishing phase of production.

One constant of every AASV Annual Meeting that I have attended has been the "drugs & bugs" portions of the educational sessions. Our best-attended sessions are those covering disease diagnosis, treatment, control, prevention, and elimination. After all these years, swine veterinarians are still intimately involved in the day-to-day health concerns on the farm. As problem-solvers by nature, we sometimes find ourselves lacking the right solutions to morbidity and mortality. Mother Nature still has a way of humbling us.

One of the best examples of a humbling disease is porcine reproductive and respiratory syndrome (PRRS). It continues to be a major subject at the annual meeting and a major source of frustration for practitioners and researchers alike. The old adage of "one step forward and two steps back" seems appropriate in describing field experiences with PRRS virus (PRRSV). While we do know more about PRRSV than we did at its first discovery, it seems that we still have a long way to go to solve this challenging disease. Since 2011, the AASV has taken the position that elimination of the PRRS virus from the North American swine industry is the long-term goal. Unfortunately, the barriers to elimination are still in place.

In recognition of the historic and ongoing challenges associated with PRRS, the AASV PRRS Task Force is embarking on a new dialogue. It is an effort to better understand the gaps in knowledge of PRRS and to examine the successes as well as the failures in PRRS control and elimination. I hope it can be an opportunity for a thoughtful approach that includes thinking in the box, beside the box, and outside the box. I suspect that it will be an intense discussion, perhaps even contentious at times. The keys to a successful dialogue will be the participants' abilities to remain respectful of differing opinions while keeping an open and objective approach to new possibilities. Setting aside our differences, biases, preconceived ideas, and proprietary interests will enable an effort resulting in action towards the shared goal of beating PRRS.

One last topic from the hallways of the meeting in Denver is the upcoming 50$^{th}$ anniversary of the AASV Annual Meeting, which takes place in 2019. In visiting with some members, it became clear that honoring our beginnings as an association is more than a maudlin display of sentimentalism. It is an appreciation and understanding of how we have survived and thrived through the decades by remaining true to our values and our mission of increasing the knowledge of swine veterinarians. I welcome the participation of our members in preparing for the 50$^{th}$ anniversary. All ideas are welcome, whether from a long-time member or a recent graduate. The key is honoring our past with an eye to a successful and sustainable future.

Tom Burkgren, DVM
Executive Director

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# Share your stories

Thank you for taking the time to pick up the May-June 2017 issue of the *Journal of Swine Health and Production* (JSHAP) and for flipping to the message pages. I can sometimes sit for hours trying to put together my message for you and sometimes I can whip the message off like a breeze. This does often depend on my own creativity, or lack thereof. I do typically like to focus the May-June issue on the activities of the journal's editorial board because I usually write this editorial on the heels of the American Association of Swine Veterinarians (AASV) Annual Meeting. During this past AASV Annual Meeting I spoke to a few members at the meeting who were kind enough to mention to me that they enjoy reading the message pages of the journal. Thank you for that. It is nice to know, and hear, that the messages are read and enjoyed. With that in mind, if there are any topics you would like to see or read about in the message pages, please do not hesitate to contact the journal office and share your ideas. And, below, I am going to ask you to send in a note or two about your own professional and non-professional activities or stories to share with me.

But, first a quick word about the editorial board of the journal. The editorial board works hard reviewing manuscripts and I had the opportunity, once again, to meet with the editorial board members face-to-face at the AASV Annual Meeting in Denver. I cannot say thank you enough to all of our editorial board members, journal staff, and reviewers for their hard work putting together such a valuable journal. The journal had a healthy number of manuscript submissions this year and the hard work of the editorial board, journal staff, and authors is reflected in the recent increase in our impact factor rating. I have talked about the journal's impact factor in the past and would like to bring your attention to the journal's impact factor again. While the impact factor of a journal can sometimes be a misleading representation of a journal's "worth," it is nonetheless an important metric in the scientific journal world. I am pleased to share with you that again, for the current reporting period, the journal's impact factor has increased. The current impact factor is 1.277 and represents another all-time high for impact factor rating for the journal. This now puts JSHAP's rating in the veterinary sciences category at 38/138. If you need a refresher of how this impact factor rating is calculated, please visit my editorial from the May-June 2016 issue.[1]

What does 2017 have in store for your calendar? I know there are quite a few people in our membership who do exciting and challenging things within and outside of veterinary medicine that have an impact on their lives and those around them. Perhaps it ranges from being a first-time parent or grandparent, a coach, doing volunteer work or charity work, or maybe you are on some other journey of self improvement? Aside from my usual professional responsibilities, for me, late 2016 and early 2017, has started me on a journey of training for long distance running. I never thought of myself as a runner. But here I am with two ½ marathons (13.1 miles) under my belt with a 19-mile race coming up in 3 weeks.

*"The current impact factor is 1.277 and represents another all-time high for impact factor rating for the journal."*

Yikes! Maybe I will consider putting a full marathon on my to-do list - maybe! I write quite a bit about my own experiences in my messages but I am interested in hearing about your stories, goals, and successes and how you got there or plan to get there. For me, the running started on a whim. I am an avid hockey player and equestrian and in my "spare time" I added running to the mix. What a challenge! It is so very different from participating in a team sport or from a sport such as equestrian events that involve an animal with his or her own agenda. It has been a challenge for me to chip away at this type of athletic training (I am not in my 20s anymore!) but the reward of crossing the finish line is very satisfying. If you are not too shy, share your stories and send them into the journal office!

## Reference

1. O'Sullivan T. Shout-out! [editorial]. *J Swine Health Prod.* 2016;24:129.

Terri O'Sullivan, DVM, PhD
Executive Editor

Original Research

Peer reviewed

# Antimicrobial susceptibility of *Actinobacillus pleuropneumoniae*, *Pasteurella multocida*, *Streptococcus suis*, and *Bordetella bronchiseptica* isolated from pigs in the United States and Canada, 2011 to 2015

Michael T. Sweeney, MS; Cynthia Lindeman, BS; Lacie Johansen, BS; Lisa Mullins, BS; Robert Murray, MS; Michael K. Senn, DVM, MS; Donald Bade, BS; Chandra Machin, BS; Susan F. Kotarski, PhD; Raksha Tiwari, DVM, PhD; Jeffrey L. Watts, PhD

## Summary

**Objective**: To report the susceptibility to veterinary antimicrobial agents of *Actinobacillus pleuropneumoniae, Pasteurella multocida, Streptococcus suis,* and *Bordetella bronchiseptica* isolated from pigs in the United States and Canada from 2011 to 2015.

**Materials and methods**: In vitro broth microdilution susceptibility testing for minimal inhibitory concentration values were performed using 10 antimicrobial agents (ampicillin, ceftiofur, danofloxacin, enrofloxacin, florfenicol, penicillin, tetracycline, tilmicosin, trimethoprim-sulfamethoxazole, and tulathromycin) with *Actinobacillu pleuropneumoniae* (n = 312), *P multocida* (n = 855), *S suis* (n = 1201), and *B bronchiseptica* (n = 572) following methods and susceptibility breakpoints approved by the Clinical and Laboratory Standards Institute.

**Results**: *Actinobacillu pleuropneumoniae* isolates were 100% susceptible to ceftiofur and florfenicol, and *P multocida* isolates were 100% susceptible to ceftiofur, enrofloxacin, and florfenicol. High rates of susceptibility (90% to > 99% susceptible) were observed for *A pleuropneumoniae* to enrofloxacin and tulathromycin, for *P multocida* to ampicillin, penicillin, tilmicosin, and tulathromycin, for *S suis* to ampicillin, ceftiofur, and florfenicol, and for *B bronchiseptica* to tulathromycin. Tetracycline exhibited low susceptibility rates against *A pleuropneumoniae* (0% to 6% susceptibility), *P multocida* (22.3% to 35.3%), and *S suis* (0% to 1.3%). No susceptibility of *B bronchiseptica* to ampicillin (0%) and low rates of susceptibility to florfenicol (5.4% to 23.5%) were also observed.

**Implications**: Under the conditions of this study, high rates of susceptibility to most veterinary antimicrobial agents continue to be seen for *A pleuropneumoniae, P multocida, S suis,* and *B bronchiseptica*, the predominant pathogens associated with swine respiratory disease in the United States and Canada.

**Keywords**: swine, surveillance, antimicrobial susceptibility, respiratory disease

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**Accepted:** November 22, 2016

**Resumen - Susceptibilidad antimicrobiana del *Actinobacillus pleuropneumoniae*, la *Pasteurella multocida*, el *Streptococcus suis*, y la *Bordetella bronchiseptica* aislados de cerdos en los Estados Unidos y Canadá, 2011 a 2015**

**Objetivo:** Reportar la susceptibilidad contra agentes antimicrobianos veterinarios del *Actinobacillus pleuropneumoniae*, la *Pasteurella multocida*, el *Streptococcus suis*, y la *Bordetella bronchiseptica* aislados de cerdos en los Estados Unidos y Canadá del 2011 al 2015.

**Materiales y métodos:** Se realizaron pruebas de susceptibilidad in vitro de microdilución en caldo para encontrar valores de concentración inhibitorios mínimos utilizando 10 agentes antimicrobianos (ampicilina, ceftiofur, danofloxacina, enrofloxacina, florfenicol, penicilina, tetraciclina, tilmicosina, trimetoprim-sulfametoxazol, y tulatromcina) con *A pleuropneumoniae* (n = 312), *P multocida* (n = 855), *S suis* (n = 1201), y *B bronchiseptica* (n = 572) siguiendo los métodos y los puntos de rompimiento de la susceptibilidad aprobados por el Instituto de Estándares Clínicos y de Laboratorio.

**Resultados:** Los aislamientos del *A pleuropneumoniae* fueron 100% susceptibles al ceftiofur y al florfenicol, y los aislados del *P multocida* fueron 100% susceptibles al ceftiofur, enrofloxacina, y al florfenicol. Se observaron altos índices de susceptibilidad (90% a > 99% susceptibles) del *A pleuropneumoniae* a la enrofloxacina y la tulatromicina, de la *P multocida* a la ampicilina, la penicilina, la tilmicosina, y la tulatromicina, del *S suis* a la ampicilina, el ceftiofur, y el florfenicol, y de la *B bronchiseptica* a la tulatromicina. La tetraciclina exhibió índices bajos de susceptibilidad contra el *A pleuropneumoniae* (0% a 6% de susceptibilidad), la *P multocida* (22.3% a 35.3%), y el *S suis* (0% a 1.3%). No hubo susceptibilidad de la *B bronchiseptica* a la ampicilina (0%) y además se observaron índices bajos de susceptibilidad al florfenicol (5.4% a 23.5%).

**Implicaciones:** Bajo las condiciones de este estudio, continúan observándose índices altos

MTS, CL, LJ, LM, RM, SFK, RT, JLW: Zoetis, Kalamazoo, Michigan.

MKS: Zoetis, Newton, Kansas.

DB, CM: Microbial Research, Inc, Fort Collins, Colorado.

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Sweeney MT, Lindeman C, Johansen L, et al. Antimicrobial susceptibility of *Actinobacillus pleuropneumoniae*, *Pasteurella multocida*, *Streptococcus suis*, and *Bordetella bronchiseptica* isolated from pigs in the United States and Canada, 2011 to 2015. *J Swine Health Prod.* 2017;25(3):106–120.

de susceptibilidad a la mayoría de los agentes antimicrobianos veterinarios contra el *A pleuropneumoniae*, la *P multocida*, el *S suis*, y la *B bronchiseptica*, los patógenos predominantes asociados con las enfermedades respiratorias porcinas en los Estados Unidos y Canadá.

**Resumé - Sensibilité antimicrobienne d'isolats porcins *d'Actinobacillus pleuropneumoniae*, de *Pasteurella multocida*, de *Streptococcus suis* et de *Bordetella bronchiseptica* provenant des États-Unis et du Canada, 2011 à 2015**

**Objectif:** Faire rapport de la sensibilité à des antimicrobiens vétérinaires d'isolats porcins *d'Actinobacillus pleuropneumoniae*, de *Pasteurella multocida*, de *Streptococcus suis*, et de *Bordetella bronchiseptica* provenant des États-Unis et du Canada de 2011 à 2015.

**Matériels et méthodes:** Les valeurs de concentration minimale inhibitrice furent déterminées in vitro par la méthode de microdilution en bouillon pour 10 agents antimicrobiens (ampicilline, ceftiofur, danofloxacine, enrofloxacine, florfénicol, pénicilline, tétracycline, tilmicosin, trimethoprime-sulfamethoxazole, et tulathromycine) pour *A pleuropneumoniae* (n = 312), *P multocida* (n = 855), *S suis* (n = 1201) et *B bronchiseptica* (n = 572) en suivant les directives et les valeurs seuils de sensibilité approuvées par le Clinical and Laboratory Standards Institute.

**Résultats:** Les isolats d*'A pleuropneumoniae* étaient sensibles à 100% au ceftiofur et au florfénicol, et les isolats de *P multocida* sensibles à 100% au ceftiofur, à l'enrofloxacine et au florfénicol. Des taux élevés de sensibilité (90% à > 99% de sensibilité) ont été notés pour *A pleuropneumoniae* envers l'enrofloxacine et la tulathromycine, pour *P multocida* envers l'ampicilline, la pénicilline, le tilmicosin et la tulathromycine, pour *S suis* envers l'ampicilline, le ceftiofur et le florfénicol, et pour *B bronchiseptica* envers la tulathromycine. La tétracycline présentait des taux faibles de sensibilité contre *A pleuropneumoniae* (0% à 6%), *P multocida* (22,3% à 35,3%), et *S suis* (0% à 1,3%). Aucune sensibilité de *B bronchiseptica* envers l'ampicilline (0%) et de faibles taux de sensibilité envers le florfénicol (5,4% à 23,5%) furent également observés.

**Implications:** Dans les conditions de la présente étude, de hauts taux de sensibilité à la plupart des agents antimicrobiens vétérinaires continuent d'être observés pour *A pleuropneumoniae*, *P multocida*, *S suis*, et *B bronchiseptica*, les principaux agents pathogènes associés avec les maladies respiratoires porcines aux États-Unis et au Canada.

Antimicrobial agents are important for the humane and efficient production of swine and other food animals in order to meet the challenges of a sustainable food supply for a growing world population.[1] According to the National Animal Health Monitoring System, swine respiratory disease (SRD) is a prevalent cause of nursery pig and grower-finisher deaths in swine in which multiple infectious agents are often involved.[2] Primary pathogens for SRD include *Mycoplasma hyopneumoniae, Actinobacillus pleuropneumoniae,* and *Bordetella bronchiseptica,* as well as viral agents. Common secondary pathogens include *Pasteurella multocida, Streptococcus suis, Hemophilus parasuis, Actinobacillus suis,* and *Salmonella* Choleraesuis.[3] These primary and secondary pathogens act together to increase the severity and duration of SRD.

Antimicrobial surveillance among veterinary bacterial pathogens obtained from clinical specimens provides a platform from which to detect emergence of resistance in animal populations. While veterinary diagnostic laboratories throughout North America provide important antimicrobial susceptibility information for clinical isolates submitted by the attending veterinarian or animal caretaker, the susceptibility results are not typically examined or summarized nationally or regionally. Few surveillance programs monitor susceptibility in swine pathogens nationally.[4,5] Portis et al[4] reported minimal inhibitory concentration (MIC) values for seven antimicrobial agents against *A pleuropneumoniae, P multocida,* and *S suis* isolated from diseased swine in the United States and Canada over a 10-year period (2001 to 2010) and concluded that most isolates showed high rates of susceptibility to all antimicrobial agents tested except tetracycline. Continuing this surveillance program, we report herein the percentages of *A pleuropneumoniae, P multocida, S suis,* and *B bronchiseptica* pathogens isolated from swine in the United States and Canada from 2011 to 2015 that were susceptible to the veterinary antimicrobial agents ampicillin, ceftiofur, danofloxacin, enrofloxacin, florfenicol, penicillin, tetracycline, tilmicosin, trimethoprim-sulfamethoxazole (TMP-SMX), and tulathromycin. This paper presents the findings of that second surveillance period (2011-2015).

## Materials and methods

### Laboratory participants and isolate characterization

Veterinary laboratories from the United States and Canada participated in this surveillance study. The regions from which isolates were obtained are shown in Table 1. All *A pleuropneumoniae, P multocida, S suis,* and *B bronchiseptica* isolates were recovered from diseased or dead pigs. Laboratories selected isolates on the basis of their own protocols and were requested not to use antimicrobial susceptibility as a criterion for selection. Laboratories were also requested to submit no more than eight isolates per quarter year in order to prevent over-representation from any one geographic area. Each participating laboratory was also requested to send no more than one isolate of each bacterial species from a herd each quarter year in order to prevent the over-representation of bacterial clones from one region.

Bacterial isolates were identified to the species level by each participating laboratory before shipment to a central laboratory for susceptibility testing. Any further identification or characterization of bacterial species were performed at Zoetis (Kalamazoo, Michigan) using standard biochemical tests, commercially available identification systems (such as API Microbial Identification Kits, bioMerieux, Durham, North Carolina; and Biolog Microbial Identification Systems, Hayward, California), or Matrix Assisted Laser Desorption Ionization Time-of-Flight Mass Spectrometry (MALDI-ToF MS, Bruker, Billerica, Massachusetts). All isolates were stored in approximately 1.0 mL trypticase soy broth (BD Biosciences, Sparks, Maryland) supplemented with 10% glycerol and stored at approximately -70°C until tested.

### Determination of minimal inhibitory concentration values

In vitro susceptibility data were generated annually by performing MIC tests at two laboratories (Microbial Research Inc, Fort Collins, Colorado; and Zoetis) to minimize testing bias.[6,7] Both laboratories followed Clinical and Laboratory Standards Institute (CLSI) standardized methods and quality-control guidelines during susceptibility testing.[8]The MIC values for all isolates were determined using a dehydrated broth microdilution system (Sensititre System; Thermo Fisher Scientific, Waltham, Massachusetts)

**Table 1:** Origin and number of bacterial isolates per year by region for a 5-year study of antimicrobial susceptibility of *Actinobacillus pleuropneumoniae*, *Pasteurella multocida*, *Streptococcus suis*, and *Bordetella bronchiseptica* from pigs in the United States and Canada*

| Region | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|
| ***Actinobacillus pleuropneumoniae*** | | | | | | |
| Canada | 12 | 13 | 14 | 14 | 16 | 69 |
| Northeast | 0 | 0 | 4 | 2 | 1 | 7 |
| Midwest | 40 | 31 | 46 | 32 | 35 | 184 |
| South | 7 | 11 | 4 | 7 | 3 | 32 |
| West | 8 | 5 | 1 | 6 | 0 | 20 |
| Total | 67 | 60 | 69 | 61 | 55 | 312 |
| ***Pasteurella multocida*** | | | | | | |
| Canada | 43 | 47 | 39 | 36 | 57 | 222 |
| Northeast | 1 | 6 | 0 | 8 | 6 | 21 |
| Midwest | 103 | 91 | 101 | 107 | 143 | 545 |
| South | 4 | 5 | 3 | 2 | 6 | 20 |
| West | 6 | 10 | 10 | 10 | 11 | 47 |
| Total | 157 | 159 | 153 | 163 | 223 | 855 |
| ***Streptococcus suis*** | | | | | | |
| Canada | 60 | 54 | 62 | 62 | 100 | 338 |
| Northeast | 3 | 9 | 0 | 6 | 8 | 26 |
| Midwest | 143 | 129 | 147 | 146 | 162 | 727 |
| South | 7 | 5 | 15 | 8 | 15 | 50 |
| West | 13 | 8 | 11 | 12 | 16 | 60 |
| Total | 226 | 205 | 235 | 234 | 301 | 1201 |
| ***Bordetella bronchiseptica*** | | | | | | |
| Canada | 24 | 17 | 21 | 17 | 32 | 111 |
| Northeast | 1 | 6 | 4 | 1 | 2 | 14 |
| Midwest | 72 | 67 | 75 | 84 | 92 | 390 |
| South | 2 | 8 | 9 | 7 | 7 | 33 |
| West | 3 | 5 | 3 | 7 | 6 | 24 |
| Total | 102 | 103 | 112 | 116 | 139 | 572 |

* Provinces and states that submitted isolates originating from within the regions included Canada: Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Quebec, Saskatchewan; Northeast: Maryland, New Jersey, New York, Pennsylvania, Vermont; Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin; South: Arkansas, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Texas, Virginia; West: Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington.

which conforms to CLSI standards for testing of veterinary pathogens.[8] Direct colony suspensions were used and prepared at a final bacterial concentration of approximately $5 \times 10^5$ colony forming units per mL. Custom-made 96-well microtitre panels included serial doubling dilutions of the antimicrobial agents ampicillin, ceftiofur, danofloxacin, enrofloxacin, florfenicol, penicillin, tetracycline, tilmicosin, TMP-SMX, and tulathromycin. All concentration ranges for antimicrobials were chosen to encompass appropriate quality-control ranges and published clinical breakpoints, and appropriate quality-control organisms were included with each testing date.[9] Ampicillin was added to the surveillance program starting in 2012, and no susceptibility data were available for 2011 alone.

# Results

## Quality control

Although not shown for this study, MIC values for all appropriate quality-control organisms were acceptable when all study isolates were tested against antimicrobial agents on each date of testing.

### *Actinobacillus pleuropneumoniae*

The MIC distributions, $MIC_{50}$ values, and $MIC_{90}$ values for 10 antimicrobial agents tested against *A pleuropneumoniae* (n = 312) are reported in Table 2. The CLSI has established clinical breakpoints for *A pleuropneumoniae* against ampicillin, ceftiofur, enrofloxacin, florfenicol, tetracycline, tilmicosin, and tulathromycin. *Actinobacillus pleuropneumoniae* susceptibility to ampicillin increased from 85% in 2012 (susceptible breakpoint ≤ 0.5 µg per mL) to 91.3% in 2013, but decreased to 85.4% in 2015. The percentage of isolates susceptible to ceftiofur over the 5-year study period was 100% (susceptible breakpoint ≤ 2 µg per mL) and the $MIC_{90}$ values were ≤ 0.03 µg per mL. The highest ceftiofur MIC value against *A pleuropneumoniae* was 1 µg per mL (2.9% of the isolates) in 2013. The percentage of susceptibility to enrofloxacin was very high (95.7% to 100%; breakpoint ≤ 0.25 µg per mL), and the $MIC_{90}$ values over the study period were 0.06 to 0.12 µg per mL; florfenicol was 100% susceptible (breakpoint ≤ 2 µg per mL), with $MIC_{90}$ values at 0.5 µg per mL. *Actinobacillus pleuropneumoniae* susceptibility to tetracycline (breakpoint ≤ 0.5 µg per mL) was very low, with 6.0% susceptibility in 2011 and 0% susceptibility in 2012, 2013, and 2015, while tilmicosin susceptibility (breakpoint ≤ 16 µg per mL) ranged from 83.6% in 2011 to 100% in 2015. There was 100% percent susceptibility of *A pleuropneumoniae* to tulathromycin (breakpoint ≤ 64 µg per mL) from 2012 to 2015, and $MIC_{90}$ values ranged from 32 to 64 µg per mL. Clinical and Laboratory Standards Institute-approved susceptible breakpoints have not been established for danofloxacin, penicillin, or TMP-SMX, but the $MIC_{90}$ values were determined as 0.12 to 0.25 µg per mL, 2 to ≥ 32 µg per mL, and ≤ 0.06 to 0.12 µg per mL, respectively, from 2011 to 2015.

### *Pasteurella multocida*

The MIC distributions, $MIC_{50}$ values, and $MIC_{90}$ values for 10 antimicrobial agents tested against *P multocida* (n = 855) are reported in Table 3. The CLSI has established clinical breakpoints for *P multocida* against ampicillin, ceftiofur, enrofloxacin, florfenicol, penicillin, tetracycline, tilmicosin, and tulathromycin. *Pasteurella multocida* susceptibility to ampicillin was very high (97.6% to 98.7%; susceptible breakpoint ≤ 0.5 µg per mL) from 2012 to 2015, while the percentage of susceptibility to ceftiofur was 100% (breakpoint ≤ 2 µg per mL), with $MIC_{90}$ values at ≤ 0.03 µg per mL. *Pasteurella multocida* was 100% susceptible to enrofloxacin (breakpoint ≤ 0.25 µg per mL) with $MIC_{90}$ values at 0.016 to 0.03 µg per mL, and also 100% susceptible to florfenicol (breakpoint ≤ 2 µg per mL) with $MIC_{90}$ values at 0.5 µg per mL. *Pasteurella multocida* isolates were highly susceptible to penicillin (97.6% to 99.4%; breakpoint ≤ 0.25 µg per mL), tilmicosin (97.5% to100%; breakpoint ≤ 16 µg per mL), and tulathromycin (98.8% to 100%; breakpoint ≤ 16 µg per mL) in which the tulathromycin $MIC_{90}$ value ranged from 2 to 4 µg per mL. Clinical and Laboratory Standards Institute-approved susceptible clinical breakpoints have not been established for danofloxacin or TMP-SMX, but $MIC_{90}$ values were determined as 0.03 to 0.06 µg per mL and 0.12 to 0.25 µg per mL, respectively.

### *Streptococcus suis*

The MIC distributions, $MIC_{50}$ values, and $MIC_{90}$ values for 10 antimicrobial agents tested against *S suis* (n = 1201) are reported in Table 4. The CLSI has established clinical breakpoints for *S suis* against ampicillin, ceftiofur, enrofloxacin, florfenicol, penicillin, and tetracycline. *Streptococcus suis* susceptibility to ampicillin was very high (susceptible breakpoint ≤ 0.5 µg per mL) and ranged from 98.0% to 99.2%, while the percentage of susceptibility to ceftiofur was also high (93.6% to 96.6%; breakpoint ≤ 2 µg per mL) over the 5-year study period in which $MIC_{90}$ values ranged from 1 to 2 µg per mL. The percentage of *S suis* susceptible to enrofloxacin (breakpoint ≤ 0.5 µg per mL) increased from 82.3% in 2011 to 94% in 2015, in which $MIC_{90}$ values were 0.5 to 1 µg per mL. The percentage of *S suis* susceptibility to florfenicol was very high (breakpoint ≤ 2 µg per mL) and dropped slightly from 100% in 2012 to 97.1% in 2015, in which $MIC_{90}$ values were 2 µg per mL. The percentage of *S suis* susceptibility to penicillin (breakpoint ≤ 0.25 µg per mL) dropped from 84% in 2011 to 73.6% in 2013, but increased to 82.1% in 2014, in which $MIC_{90}$ values ranged from 1 to 2 µg per mL. No *S suis* isolates were susceptible to tetracycline (breakpoint ≤ 1 µg per mL) in 2012 and 2015, with 0.8% susceptibility in 2011 and 1.3% susceptibility in 2013 and 2014. Susceptible breakpoints were not available for danofloxacin, tilmicosin, TMP-SMX, or tulathromycin, but $MIC_{90}$ values were determined as 1 µg per mL, ≥ 64 µg per mL, 0.12 to 0.25 µg per mL, and ≥ 128 µg per mL, respectively.

### *Bordetella bronchiseptica*

The MIC distributions, $MIC_{50}$ values, and $MIC_{90}$ values for 10 antimicrobial agents tested against *B bronchiseptica* (n = 572) are reported in Table 5. The CLSI has established clinical breakpoints for *B bronchiseptica* against ampicillin, florfenicol, and tulathromycin. *Bordetella bronchiseptica* isolates in this study had no in vitro activity to ampicillin (0% susceptibility; susceptible breakpoint ≤ 0.5 µg per mL) in which $MIC_{90}$ values were ≥ 16 µg per mL. *Bordetella bronchiseptica* susceptibility to florfenicol (breakpoint ≤ 2 µg per mL) was low and decreased from 23.5 % in 2011 to 5.4% in 2013, but increased to 11.2% in 2014, in which $MIC_{90}$ values were 4 µg per mL over the 5-year study period. The percentage of *B bronchiseptica* susceptible to tulathromycin was 99% to 100% (breakpoint ≤ 16 µg per mL) and the $MIC_{90}$ value ranged from 8 to 16 µg per mL. Clinical and Laboratory Standards Institute-approved susceptible breakpoints were not available for ceftiofur, danofloxacin, enrofloxacin, penicillin, tetracycline, tilmicosin, or TMP-SMX, but $MIC_{90}$ values were determined as ≥ 8 µg per mL, 1 µg per mL, 0.5 to 1 µg per mL, ≥ 32 µg per mL, 2 to 4 µg per mL, 32 to ≥ 64 µg per mL, and 8 to ≥ 16 µg per mL, respectively.

## Discussion

The availability of antimicrobial agents to combat respiratory disease in veterinary medicine continues to have a beneficial effect on the health and welfare of swine and other livestock, and the use of antimicrobial agents helps support the safe, humane, and economical production of food.[10] The prevalence of *A pleuropneumoniae, P multocida, S suis*, and *B bronchiseptica* pathogens associated with SRD emphasizes the importance of maintaining high levels of susceptibility to antimicrobial agents that are available to veterinarians for treatment of these pathogens.[11] Surveillance and monitoring studies for antimicrobial resistance in pathogenic bacteria of animal origin are necessary to understand any rates of change in the susceptibility of bacteria to antimicrobial agents, thereby serving as one component among many to help guide practitioners to select the most appropriate antimicrobial agent for treatment of disease.[12] A limited number of recent studies have investigated in vitro susceptibilities of specific antimicrobial agents used to treat swine pathogens associated with respiratory disease on a national basis.[4,5,13,14]

**Table 2:** Summary of minimal inhibitory concentration (MIC) values and frequency distributions for 10 antimicrobial agents tested with *Actinobacillus pleuropneumoniae* (n = 312) isolated from swine in the United States and Canada from 2011 to 2015*

| | | | | | Ampicillin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | | | | | | | NT | | | | | | |
| 2012 | 60 | 0.12 | ≥ 16 | 85 | 1.7 | 48.3 | 33.3 | 1.7 | 0 | 0 | 0 | 0 | 15 |
| 2013 | 69 | 0.25 | 0.5 | 91.3 | 2.9 | 23.2 | 56.5 | 8.7 | 0 | 1.4 | 0 | 0 | 7.3 |
| 2014 | 61 | 0.25 | ≥ 16 | 86.9 | 0 | 41 | 45.9 | 0 | 0 | 1.6 | 0 | 0 | 11.5 |
| 2015 | 55 | 0.25 | ≥ 16 | 85.4 | 3.6 | 41.8 | 40 | 0 | 0 | 0 | 1.8 | 0 | 12.8 |

| | | | | | Ceftiofur MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | ≥ 8 |
| 2011 | 67 | ≤ 0.03 | ≤ 0.03 | 100 | 98.5 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 60 | ≤ 0.03 | ≤ 0.03 | 100 | 93.3 | 6.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 69 | ≤ 0.03 | ≤ 0.03 | 100 | 95.7 | 1.4 | 0 | 0 | 0 | 2.9 | 0 | 0 | 0 |
| 2014 | 61 | ≤ 0.03 | ≤ 0.03 | 100 | 95.1 | 4.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 55 | ≤ 0.03 | ≤ 0.03 | 100 | 98.2 | 1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | Danofloxacin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.016 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | ≥ 4 |
| 2011 | 67 | 0.06 | 0.12 | NA | 0 | 0 | 64.2 | 31.3 | 1.5 | 1.5 | 1.5 | 0 | 0 |
| 2012 | 60 | 0.06 | 0.12 | NA | 0 | 0 | 53.3 | 43.3 | 1.7 | 0 | 1.7 | 0 | 0 |
| 2013 | 69 | 0.12 | 0.25 | NA | 1.5 | 0 | 34.8 | 53.6 | 5.8 | 1.5 | 2.9 | 0 | 0 |
| 2014 | 61 | 0.12 | 0.12 | NA | 0 | 0 | 32.8 | 65.6 | 1.6 | 0 | 0 | 0 | 0 |
| 2015 | 55 | 0.12 | 0.12 | NA | 0 | 1.8 | 36.4 | 60 | 1.8 | 0 | 0 | 0 | 0 |

| | | | | | Enrofloxacin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.008 | 0.016 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | ≥ 2 |
| 2011 | 67 | 0.06 | 0.06 | 98.5 | 0 | 0 | 25.4 | 68.6 | 3 | 1.5 | 1.5 | 0 | 0 |
| 2012 | 60 | 0.06 | 0.12 | 98.3 | 0 | 0 | 23.3 | 65 | 10 | 0 | 0 | 1.7 | 0 |
| 2013 | 69 | 0.06 | 0.12 | 95.7 | 1.4 | 0 | 20.3 | 59.5 | 14.5 | 0 | 4.3 | 0 | 0 |
| 2014 | 61 | 0.06 | 0.12 | 100 | 0 | 0 | 21.3 | 67.2 | 11.5 | 0 | 0 | 0 | 0 |
| 2015 | 55 | 0.06 | 0.06 | 100 | 0 | 1.8 | 29.1 | 61.8 | 7.3 | 0 | 0 | 0 | 0 |

| | | | | | Florfenicol MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 67 | 0.25 | 0.5 | 100 | 0 | 0 | 52.2 | 47.8 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 60 | 0.5 | 0.5 | 100 | 0 | 1.7 | 36.7 | 61.6 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 69 | 0.5 | 0.5 | 100 | 0 | 0 | 30.4 | 68.1 | 0 | 1.5 | 0 | 0 | 0 |
| 2014 | 61 | 0.5 | 0.5 | 100 | 0 | 0 | 42.6 | 57.4 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 55 | 0.5 | 0.5 | 100 | 0 | 0 | 25.5 | 74.5 | 0 | 0 | 0 | 0 | 0 |

| | | | | | Penicillin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | ≥ 32 |
| 2011 | 67 | 0.5 | ≥ 32 | NA | 7.5 | 19.4 | 47.8 | 7.5 | 1.5 | 0 | 0 | 1.5 | 14.9 |
| 2012 | 60 | 0.5 | ≥ 32 | NA | 5 | 15 | 51.7 | 13.3 | 0 | 0 | 0 | 0 | 15 |
| 2013 | 69 | 0.5 | 2 | NA | 7.2 | 24.6 | 56.5 | 1.5 | 1.5 | 1.5 | 0 | 0 | 7.2 |
| 2014 | 61 | 0.25 | ≥ 32 | NA | 8.2 | 47.5 | 28 | 1.6 | 1.6 | 0 | 1.6 | 0 | 11.5 |
| 2015 | 55 | 0.5 | ≥ 32 | NA | 7.3 | 30.9 | 47.3 | 0 | 0 | 1.8 | 0 | 0 | 12.8 |

**Table 2:** Continued

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tetracycline MIC frequency distribution (% of isolates) ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 67 | ≥ 16 | ≥ 16 | 6 | 1.5 | 4.5 | 11.9 | 0 | 3 | 17.9 | 61.2 |
| 2012 | 60 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 16.7 | 3.3 | 0 | 18.3 | 61.7 |
| 2013 | 69 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 10.1 | 1.5 | 0 | 17.4 | 71 |
| 2014 | 61 | ≥ 16 | ≥ 16 | 3.3 | 0 | 3.3 | 16.4 | 1.6 | 0 | 24.6 | 51.4 |
| 2015 | 55 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 9.1 | 0 | 0 | 21.8 | 69.1 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tilmicosin MIC frequency distribution (% of isolates) ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | ≥ 64 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 67 | 16 | 32 | 83.6 | 0 | 0 | 0 | 0 | 0 | 10.5 | 73.1 | 16.4 | 0 |
| 2012 | 60 | 8 | 16 | 98.3 | 0 | 0 | 0 | 0 | 3.3 | 73.3 | 21.7 | 1.7 | 0 |
| 2013 | 69 | 16 | 32 | 89.9 | 0 | 0 | 0 | 0 | 1.5 | 36.2 | 52.2 | 10.1 | 0 |
| 2014 | 61 | 16 | 16 | 96.7 | 0 | 0 | 0 | 0 | 0 | 14.7 | 82 | 3.3 | 0 |
| 2015 | 55 | 8 | 16 | 100 | 0 | 0 | 0 | 0 | 1.8 | 56.4 | 41.8 | 0 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | TMP-SMX MIC frequency distribution (% of isolates) ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 67 | ≤ 0.06 | ≤ 0.06 | NA | 92.5 | 7.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 60 | ≤ 0.06 | ≤ 0.06 | NA | 98.3 | 1.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 69 | ≤ 0.06 | ≤ 0.06 | NA | 92.8 | 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 61 | ≤ 0.06 | 0.12 | NA | 83.6 | 16.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 55 | ≤ 0.06 | 0.12 | NA | 67.3 | 30.9 | 1.8 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tulathromycin MIC frequency distribution (% of isolates) ≤ 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | ≥ 128 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 67 | 64 | 64 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 11.9 | 86.6 | 1.5 |
| 2012 | 60 | 16 | 32 | 100 | 0 | 0 | 0 | 0 | 1.7 | 48.3 | 50 | 0 | 0 |
| 2013 | 69 | 32 | 64 | 100 | 0 | 0 | 0 | 0 | 0 | 7.2 | 66.7 | 26.1 | 0 |
| 2014 | 61 | 64 | 64 | 100 | 0 | 0 | 0 | 0 | 0 | 4.9 | 37.7 | 57.4 | 0 |
| 2015 | 55 | 32 | 64 | 100 | 0 | 0 | 0 | 0 | 1.8 | 9.1 | 78.2 | 12.7 | 0 |

* No. = the number of isolates tested per year; $MIC_{50}$ = antibacterial drug concentration that inhibits 50% of the bacterial population; $MIC_{90}$ = antibacterial drug concentration that inhibits 90% of the bacterial population; %S = the percentage of isolates that are susceptible to the antibacterial drug using Clinical and Laboratory Standards Institute (CLSI) criteria; NA = not applicable since there are no CLSI-approved clinical breakpoints for susceptibility in that swine respiratory disease pathogen; NT = not tested; vertical bold lines indicate the CLSI-approved breakpoint for susceptible, intermediate, and resistant in that swine respiratory disease pathogen; TMP-SMX = trimethoprim-sulfamethoxazole; numbers in the lowest concentration of the tested antibacterial drug range represents the percentage of isolates that had MICs less than or equal to the lowest drug concentration tested per year, while numbers above the highest antibacterial drug concentration represent the percentage of isolates that had MICs greater than the highest drug concentration tested that year. Percent MIC frequency rows may not add to 100% due to rounding.

The SRD surveillance program reported herein has continuously obtained swine pathogens for over 15 years from veterinary diagnostic laboratories in North America, that have then been tested for antimicrobial susceptibility. The purpose for this ongoing surveillance study was to summarize the antimicrobial susceptibility profiles of 2940 isolates of four different pathogenic bacterial species associated with SRD collected from laboratories in the United States and Canada over a 5-year period from 2011 to 2015.

To our knowledge, when coupled with our published SRD surveillance data from 2001 to 2010,[4] this is the only surveillance program that has collected and published 15 years of SRD susceptibility data against a total of 9043 isolates from the United States and Canada. Susceptibility data from this ongoing surveillance study may be used as an indicator for the emergence of bacterial resistance, a feature which is found in other antimicrobial susceptibility surveillance programs.[5,13,15] In addition to presenting summarized values such as $MIC_{50}$, $MIC_{90}$, and range values for the antimicrobial drugs, this report also includes the MIC frequencies for all available years in order to provide evidence of potential antimicrobial susceptibility changes among the SRD pathogens collected from 2011 to 2015. The presentation of MIC frequencies allows for the observation of any MIC shifts that may not be reflected with $MIC_{50}$, $MIC_{90}$, or percent susceptibility values.

**Table 3:** Summary of minimal inhibitory concentration (MIC) values and frequency distributions for 10 antimicrobial agents tested with *Pasteurella multocida* (n = 855) isolated from swine in the United States and Canada from 2011 to 2015*

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Ampicillin MIC frequency distribution (% of isolates) ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | | | | | NT | | | | | | | | |
| 2012 | 159 | 0.12 | 0.12 | 98.6 | 32 | 64.2 | 2.5 | 0 | 0 | 0 | 0 | 0 | 1.2 |
| 2013 | 153 | 0.12 | 0.25 | 98 | 19.6 | 67.3 | 11.1 | 0 | 0 | 0 | 0 | 0 | 2 |
| 2014 | 163 | 0.12 | 0.12 | 97.6 | 41.1 | 49.1 | 7.4 | 0 | 0 | 0 | 0.6 | 0 | 1.8 |
| 2015 | 223 | 0.12 | 0.12 | 98.7 | 41.7 | 53.4 | 3.6 | 0 | 0 | 0 | 0 | 0 | 1.3 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Ceftiofur MIC frequency distribution (% of isolates) ≤ 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | ≥ 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 157 | ≤ 0.03 | ≤ 0.03 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 159 | ≤ 0.03 | ≤ 0.03 | 100 | 97.4 | 1.3 | 1.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 153 | ≤ 0.03 | ≤ 0.03 | 100 | 90.2 | 3.9 | 5.2 | 0.7 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 163 | ≤ 0.03 | ≤ 0.03 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 223 | ≤ 0.03 | ≤ 0.03 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Danofloxacin MIC frequency distribution (% of isolates) ≤ 0.016 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | ≥ 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 157 | ≤ 0.016 | 0.03 | NA | 54.8 | 38.9 | 5.1 | 1.2 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 159 | ≤ 0.016 | 0.03 | NA | 62.9 | 34 | 3.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 153 | 0.03 | 0.06 | NA | 42.5 | 46.4 | 11.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 163 | ≤ 0.016 | 0.03 | NA | 60.2 | 30.6 | 8 | 0.6 | 0.6 | 0 | 0 | 0 | 0 |
| 2015 | 223 | 0.015 | 0.03 | NA | 53.8 | 42.6 | 3.6 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Enrofloxacin MIC frequency distribution (% of isolates) ≤ 0.008 | 0.016 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | ≥ 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 157 | 0.016 | 0.03 | 100 | 14.6 | 66.3 | 15.9 | 3.2 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 159 | 0.016 | 0.03 | 100 | 30.2 | 56 | 13.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 153 | 0.016 | 0.03 | 100 | 18.9 | 54.9 | 24.2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 163 | ≤ 0.008 | 0.03 | 100 | 57.7 | 31.3 | 7.4 | 3.1 | 0.5 | 0 | 0 | 0 | 0 |
| 2015 | 223 | ≤ 0.008 | 0.016 | 100 | 61.9 | 32.3 | 5.4 | 0.4 | 0 | 0 | 0 | 0 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Florfenicol MIC frequency distribution (% of isolates) ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 157 | 0.5 | 0.5 | 100 | 0 | 0.6 | 7.6 | 89.8 | 2 | 0 | 0 | 0 | 0 |
| 2012 | 159 | 0.5 | 0.5 | 100 | 1.3 | 0 | 13.2 | 84.3 | 1.3 | 0 | 0 | 0 | 0 |
| 2013 | 153 | 0.5 | 0.5 | 100 | 0 | 0 | 6.5 | 93.5 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 163 | 0.5 | 0.5 | 100 | 0.6 | 0 | 6.8 | 86.5 | 6.1 | 0 | 0 | 0 | 0 |
| 2015 | 223 | 0.5 | 0.5 | 100 | 0.9 | 0 | 2.2 | 90.6 | 5.8 | 0.5 | 0 | 0 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Penicillin MIC frequency distribution (% of isolates) ≤ 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | ≥ 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 157 | ≤ 0.12 | ≤ 0.12 | 99.4 | 91.8 | 7.6 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 |
| 2012 | 159 | ≤ 0.12 | ≤ 0.12 | 98.8 | 98.2 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0.6 |
| 2013 | 153 | ≤ 0.12 | ≤ 0.12 | 98.1 | 93.5 | 4.6 | 0 | 0 | 0 | 0 | 0 | 0 | 1.9 |
| 2014 | 163 | ≤ 0.12 | ≤ 0.12 | 97.6 | 95.8 | 1.8 | 0 | 0 | 0 | 0 | 0.6 | 0 | 1.8 |
| 2015 | 223 | ≤ 0.12 | ≤ 0.12 | 98.6 | 98.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.4 |

**Table 3:** Continued

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tetracycline MIC frequency distribution (% of isolates) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≤ 16 |
| 2011 | 157 | 2 | ≤ 16 | 28.7 | 1.9 | 26.8 | 15.3 | 33.1 | 6.4 | 1.2 | 15.3 |
| 2012 | 159 | 2 | ≥ 16 | 35.3 | 5.7 | 29.6 | 12 | 27 | 2.5 | 3.1 | 20.1 |
| 2013 | 153 | 2 | ≥ 16 | 22.3 | 0.7 | 21.6 | 10.5 | 42.4 | 2.6 | 2 | 20.2 |
| 2014 | 163 | 2 | ≥ 16 | 27.6 | 5.5 | 22.1 | 13.5 | 35.6 | 4.3 | 3.7 | 15.3 |
| 2015 | 223 | 2 | ≥ 16 | 31.4 | 1.4 | 30 | 5.4 | 39 | 3.6 | 2.2 | 18.4 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tilmicosin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | ≥ 64 |
| 2011 | 157 | 4 | 16 | 100 | 0 | 0 | 3.2 | 19.8 | 38.2 | 24.8 | 14 | 0 | 0 |
| 2012 | 159 | 4 | 8 | 97.5 | 1.3 | 0 | 1.9 | 18.9 | 39.6 | 28.9 | 6.9 | 0.6 | 1.9 |
| 2013 | 153 | 4 | 16 | 99.3 | 0 | 0 | 2.6 | 18.3 | 44.4 | 21.6 | 12.4 | 0 | 0.7 |
| 2014 | 163 | 4 | 16 | 98.2 | 0 | 0 | 5.5 | 9.2 | 36.8 | 24.5 | 22.1 | 0.6 | 1.2 |
| 2015 | 223 | 8 | 16 | 97.8 | 0 | 0.4 | 0.9 | 8.5 | 38.1 | 29.6 | 20.2 | 2.2 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | TMP-SMX MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 157 | ≤ 0.06 | 0.12 | NA | 75.8 | 17.2 | 4.5 | 0.6 | 0.6 | 1.3 | 0 | 0 | 0 |
| 2012 | 159 | ≤ 0.06 | 0.12 | NA | 68.6 | 27 | 3.8 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 153 | ≤ 0.06 | 0.25 | NA | 69.3 | 19.6 | 7.8 | 1.3 | 0 | 0 | 0 | 0 | 2 |
| 2014 | 163 | ≤ 0.06 | 0.12 | NA | 73.6 | 20.3 | 4.3 | 1.2 | 0.6 | 0 | 0 | 0 | 0 |
| 2015 | 223 | ≤ 0.06 | 0.12 | NA | 62.3 | 30.9 | 4 | 1.3 | 0 | 0.4 | 0 | 0 | 1 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tulathromycin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | ≥ 128 |
| 2011 | 157 | 2 | 4 | 100 | 6.4 | 24.2 | 44.6 | 15.2 | 9.6 | 0 | 0 | 0 | 0 |
| 2012 | 159 | 1 | 2 | 98.8 | 24.5 | 32.1 | 35.2 | 6.9 | 0 | 0 | 0.6 | 0.6 | 0 |
| 2013 | 153 | 1 | 2 | 100 | 13.7 | 49 | 30.1 | 7.2 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 163 | 2 | 4 | 100 | 11.7 | 31.3 | 30.7 | 22.7 | 3.7 | 0 | 0 | 0 | 0 |
| 2015 | 223 | 2 | 4 | 100 | 6.7 | 22.9 | 38.1 | 28.7 | 3.5 | 0 | 0 | 0 | 0 |

* No. = the number of isolates tested per year; $MIC_{50}$ = antibacterial drug concentration that inhibits 50% of the bacterial population; $MIC_{90}$ = antibacterial drug concentration that inhibits 90% of the bacterial population; %S = the percentage of isolates that are susceptible to the antibacterial drug using Clinical and Laboratory Standards Institute (CLSI) criteria; NA = not applicable since there are no CLSI-approved clinical breakpoints for susceptibility in that swine respiratory disease pathogen; NT = not tested; vertical bold lines indicate the CLSI-approved breakpoint for susceptible, intermediate, and resistant in that swine respiratory disease pathogen; TMP-SMX = trimethoprim-sulfamethoxazole; numbers in the lowest concentration of the tested antibacterial drug range represent the percentage of isolates that had MICs less than or equal to the lowest drug concentration tested per year, while numbers above the highest antibacterial drug concentration represent the percentage of isolates that had MICs greater than the highest drug concentration tested that year. Percent MIC frequency rows may not add to 100% due to rounding.

Retrospective studies have been published that investigated the antimicrobial susceptibility of *A pleuropneumoniae* isolates from swine. Archambault et al[16] reported the antimicrobial susceptibilities of 43 isolates of *A pleuropneumoniae* from Canada in which all isolates were 100% susceptible to ceftiofur, florfenicol, enrofloxacin, erythromycin, clindamycin, TMP-SMX, and tilmicosin, but reported a low level of susceptibility to chlortetracycline and oxytetracycline (11.6% and 9.3% susceptibility, respectively). A study by Vanni et al[17] also showed high antimicrobial susceptibility for 992 isolates of *A pleuropneumoniae* to amphenicols, fluoroquinolones, and ceftiofur, while low rates of susceptibility were observed for tetracycline (< 17%) and penicillin (< 15%). El Garch et al[18] reported the susceptibilities of 158 *A pleuropneumoniae* isolates isolated from pigs in 2009 to 2012 that showed 100% susceptibility to amoxicillin-clavulanate, ceftiofur, tiamulin, and tulathromycin with 96% to > 99% susceptibility to enrofloxacin, florfenicol, and tilmicosin, while tetracycline susceptibility was reported at 70%. Finally, Dayao et al[14] reported 100% susceptibility to ceftiofur, florfenicol, and tulathromycin for 71 isolates. Susceptibility data for *A pleuropneumoniae* from our 2001 to 2010 SRD surveillance program reported 100% susceptibility to ceftiofur, florfenicol, and tulathromycin.[4]The high susceptibility rates

**Table 4:** Summary of minimal inhibitory concentration (MIC) values and frequency distributions for 10 antimicrobial agents tested with *Streptococcus suis* (n = 1201) isolated from swine in the United States and Canada from 2011 to 2015*

| Year | No. | $MIC_{50}$ (µ/mL) | $MIC_{90}$ (µg/mL) | %S | Ampicillin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | | | | | | | NT | | | | | | |
| 2012 | 205 | ≤ 0.03 | 0.12 | 98.6 | 86.9 | 7.3 | 4.4 | 0 | 0 | 0.5 | 0.5 | 0.5 | 0 |
| 2013 | 235 | ≤ 0.03 | 0.12 | 98 | 83.4 | 8.1 | 5.5 | 0.9 | 0.9 | 0.8 | 0.4 | 0 | 0 |
| 2014 | 234 | ≤ 0.03 | 0.12 | 99.2 | 88.9 | 6.8 | 3 | 0.4 | 0.9 | 0 | 0 | 0 | 0 |
| 2015 | 301 | ≤ 0.03 | 0.12 | 99.1 | 89.4 | 6 | 3 | 0.6 | 0.3 | 0.3 | 0 | 0.3 | 0 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Ceftiofur MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | ≥ 8 |
| 2011 | 226 | 0.12 | 1 | 96.5 | 15 | 34.5 | 20.4 | 7.1 | 11.1 | 6.2 | 2.2 | 2.2 | 1.3 |
| 2012 | 205 | 0.12 | 1 | 96.6 | 9.3 | 35.1 | 26.3 | 3.9 | 8.8 | 8.8 | 4.4 | 1 | 2.5 |
| 2013 | 235 | 0.12 | 2 | 93.6 | 38.3 | 20.9 | 7.2 | 8.1 | 10.6 | 8.5 | 3 | 1.3 | 2.1 |
| 2014 | 234 | 0.12 | 1 | 96.2 | 5.1 | 37.6 | 32.1 | 5.6 | 4.7 | 6 | 5.1 | 1.3 | 2.5 |
| 2015 | 301 | 0.12 | 1 | 93.9 | 6.3 | 36.2 | 28.9 | 5.3 | 7.6 | 7.3 | 2.3 | 0.7 | 5.4 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Danofloxacin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.015 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | ≥ 4 |
| 2011 | 226 | 0.5 | 1 | NA | 0 | 0 | 1.3 | 3.1 | 21.2 | 52.7 | 18.1 | 2.2 | 1.4 |
| 2012 | 205 | 0.5 | 1 | NA | 0 | 0 | 0.5 | 4.4 | 22.4 | 52.7 | 18 | 2 | 0 |
| 2013 | 235 | 0.5 | 1 | NA | 0 | 0 | 0.9 | 2.1 | 16.2 | 51.9 | 23.8 | 2.6 | 2.6 |
| 2014 | 234 | 0.5 | 1 | NA | 0 | 0 | 0.9 | 3.8 | 13.2 | 62.4 | 16.2 | 2.1 | 1.3 |
| 2015 | 301 | 0.5 | 1 | NA | 0.3 | 0.3 | 0.3 | 2.3 | 10.6 | 59.1 | 25.3 | 0.3 | 1.3 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Enrofloxacin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.008 | 0.016 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | ≥ 2 |
| 2011 | 226 | 0.5 | 1 | 82.3 | 0 | 0 | 0 | 1.8 | 6.6 | 23.5 | 50.4 | 15 | 2.7 |
| 2012 | 205 | 0.5 | 1 | 84 | 0 | 0 | 0 | 0.5 | 5.4 | 25.4 | 52.7 | 13.6 | 2.4 |
| 2013 | 235 | 0.5 | 1 | 84.3 | 0 | 0 | 0.4 | 0.4 | 5.5 | 30.6 | 47.2 | 11.2 | 4.7 |
| 2014 | 234 | 0.5 | 0.5 | 95.3 | 0 | 0 | 0.4 | 0.9 | 8.1 | 39.7 | 46.2 | 3.4 | 1.3 |
| 2015 | 301 | 0.5 | 0.5 | 94 | 0 | 0 | 0.3 | 0.7 | 7.3 | 33.2 | 52.5 | 4.7 | 1.3 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Florfenicol MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 226 | 2 | 2 | 99.1 | 0 | 0.4 | 0 | 6.6 | 42.5 | 49.6 | 0.9 | 0 | 0 |
| 2012 | 205 | 2 | 2 | 100 | 0 | 0 | 0 | 3.9 | 34.6 | 61.5 | 0 | 0 | 0 |
| 2013 | 235 | 2 | 2 | 99.6 | 0 | 0 | 0.4 | 3 | 33.2 | 63 | 0.4 | 0 | 0 |
| 2014 | 234 | 2 | 2 | 97.9 | 0 | 0 | 0.4 | 3.4 | 27.4 | 66.7 | 2.1 | 0 | 0 |
| 2015 | 301 | 2 | 2 | 97.1 | 0 | 0 | 0 | 2.7 | 20.9 | 73.5 | 2.3 | 0 | 0.6 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Penicillin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | ≥ 32 |
| 2011 | 226 | ≤ 0.12 | 1 | 84 | 80.5 | 3.5 | 2.7 | 4 | 4.9 | 4 | 0 | 0.4 | 0 |
| 2012 | 205 | ≤ 0.12 | 1 | 81.5 | 77.6 | 3.9 | 3.9 | 5.4 | 3.4 | 4.4 | 1 | 0.5 | 0 |
| 2013 | 235 | ≤ 0.12 | 2 | 73.6 | 69.8 | 3.8 | 5.1 | 6.8 | 6.8 | 5.5 | 1.3 | 0.9 | 0 |
| 2014 | 234 | ≤ 0.12 | 2 | 82.1 | 79.5 | 2.6 | 3 | 3.8 | 4.8 | 3.8 | 1.7 | 0.4 | 0.4 |
| 2015 | 301 | ≤ 0.12 | 2 | 80.1 | 75.8 | 4.3 | 5.6 | 3.7 | 3 | 5.6 | 1.7 | 0 | 0.3 |

**Table 4:** Continued

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tetracycline MIC frequency distribution (% of isolates) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 226 | ≥ 16 | ≥ 16 | 0.8 | 0.4 | 0.4 | 0 | 0 | 3.2 | 1.8 | 94.2 |
| 2012 | 205 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 2 | 0.5 | 1.5 | 1.5 | 94.5 |
| 2013 | 235 | ≥ 16 | ≥ 16 | 1.3 | 1.3 | 0 | 0.9 | 2.1 | 1.7 | 0.9 | 93.1 |
| 2014 | 234 | ≥ 16 | ≥ 16 | 1.3 | 0.4 | 0.9 | 0 | 0.9 | 2.6 | 0.9 | 94.3 |
| 2015 | 301 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 0.3 | 1 | 2.7 | 1.7 | 94.3 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tilmicosin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | ≥ 64 |
| 2011 | 226 | ≥ 64 | ≥ 64 | NA | 1.8 | 0 | 3.5 | 16.8 | 2.7 | 0.9 | 0 | 0 | 74.3 |
| 2012 | 205 | ≥ 64 | ≥ 64 | NA | 1.5 | 2.4 | 7.8 | 10.7 | 1 | 0.5 | 0 | 0 | 76.1 |
| 2013 | 235 | ≥ 64 | ≥ 64 | NA | 1.3 | 0 | 0 | 0.9 | 10.6 | 13.6 | 0.4 | 0 | 73.2 |
| 2014 | 234 | ≥ 64 | ≥ 64 | NA | 0 | 0 | 0.4 | 0.4 | 14.5 | 6.8 | 0 | 0 | 77.9 |
| 2015 | 301 | ≥ 64 | ≥ 64 | NA | 0 | 0.3 | 0 | 0.7 | 7 | 9.6 | 0.7 | 0 | 81.7 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | TMP-SMX MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 226 | ≤ 0.06 | 0.12 | NA | 86.7 | 8.4 | 1.3 | 1.3 | 1.8 | 0 | 0 | 0.4 | 0 |
| 2012 | 205 | ≤ 0.06 | 0.12 | NA | 86.8 | 10.2 | 2 | 0.5 | 0 | 0.5 | 0 | 0 | 0 |
| 2013 | 235 | ≤ 0.06 | 0.25 | NA | 63 | 25.1 | 3 | 2.1 | 2.6 | 0.9 | 0.9 | 0.4 | 2.1 |
| 2014 | 234 | ≤ 0.06 | 0.12 | NA | 83 | 9.4 | 1.3 | 0.9 | 1.7 | 0.9 | 0.4 | 0.4 | 2 |
| 2015 | 301 | ≤ 0.06 | 0.12 | NA | 73.8 | 17.6 | 3.3 | 0 | 1 | 0 | 1.3 | 0.3 | 2.7 |

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tulathromycin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | ≥ 128 |
| 2011 | 226 | ≥ 128 | ≥ 128 | NA | 15.5 | 6.2 | 3.1 | 0.4 | 0.9 | 0.9 | 1.8 | 5.7 | 65.5 |
| 2012 | 205 | ≥ 128 | ≥ 128 | NA | 18.5 | 4.9 | 0.5 | 0 | 2 | 2 | 3.9 | 12.7 | 55.6 |
| 2013 | 235 | ≥ 128 | ≥ 128 | NA | 1.7 | 3 | 8.9 | 13.2 | 0.9 | 0 | 0.4 | 1.3 | 70.6 |
| 2014 | 234 | ≥ 128 | ≥ 128 | NA | 1.3 | 3 | 9.8 | 8.6 | 0 | 0 | 1.3 | 3.4 | 72.6 |
| 2015 | 301 | ≥ 128 | ≥ 128 | NA | 0.6 | 1.3 | 5.3 | 10.3 | 0.7 | 0.3 | 0.3 | 2.7 | 78.4 |

* No. = the number of isolates tested per year; $MIC_{50}$ = antibacterial drug concentration that inhibits 50% of the bacterial population; $MIC_{90}$ = antibacterial drug concentration that inhibits 90% of the bacterial population; %S = the percentage of isolates that are susceptible to the antibacterial drug using Clinical and Laboratory Standards Institute (CLSI) criteria; NA = not applicable since there are no CLSI-approved clinical breakpoints for susceptibility in that swine respiratory disease pathogen; NT = not tested; vertical bold lines indicate the CLSI-approved breakpoint for susceptible, intermediate, and resistant in that swine respiratory disease pathogen; TMP-SMX = trimethoprim-sulfamethoxazole; numbers in the lowest concentration of the tested antibacterial drug range represents the percentage of isolates that had MICs less than or equal to the lowest drug concentration tested per year, while numbers above the highest antibacterial drug concentration represent the percentage of isolates that had MICs greater than the highest drug concentration tested that year. Percent MIC frequency rows may not add to 100% due to rounding.

from these reports are consistent with observations reported herein in which 100% susceptibility to ceftiofur and florfenicol, high levels of susceptibility (> 90% to 100%) to enrofloxacin and tulathromycin, and low levels of susceptibility (0% to 6%) to tetracycline were observed for 312 isolates of *A pleuropneumoniae* from 2011 to 2015. Additionally, the $MIC_{90}$ values for ceftiofur (≤ 0.06 µg per mL) and florfenicol (0.5 µg per mL) with *A pleuropneumoniae* have remained well below the susceptible breakpoints since 2001.[4]

For *P multocida* isolated from swine, Glass-Kaastra et al[19] published results on 1464 isolates collected from 1998 to 2010 in which susceptibility to ampicillin remained high from 1998 to 2007, with slightly decreased susceptibility from 2007 to 2010, while tetracycline susceptibility ranged from 60% to 90%. Dayao et al[14] reported 100% susceptibility to ceftiofur, tilmicosin, and tulathromycin for 51 isolates, and El Garch et al[18] reported 100% susceptibility for 152 *P multocida* isolates from pigs to amoxicillin-clavulanate, ceftiofur, enrofloxacin, and tulathromycin and 65.8% susceptibility to tetracycline. Susceptibility data for 2001 to 2010[4] from our SRD surveillance program reported 100% susceptibility to ceftiofur with high rates of susceptibility (> 90% to 100%) to enrofloxacin, florfenicol, tilmicosin, and tulathromycin. This current report shows 100% susceptibility

**Table 5:** Summary of minimal inhibitory concentration (MIC) values and frequency distributions for 10 antimicrobial agents tested with *Bordetella bronchiseptica* (n = 572) isolated from swine in the United States and Canada from 2011 to 2015*

| | | | | | Ampicillin MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | | | | | | | NT | | | | | | |
| 2012 | 103 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2.9 | 96.1 |
| 2013 | 112 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.3 | 93.7 |
| 2014 | 116 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | 0.9 | 3.5 | 93.9 |
| 2015 | 139 | ≥ 16 | ≥ 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.2 | 4.3 | 93.6 |
| | | | | | Ceftiofur MIC frequency distribution (% of isolates) | | | | | | | | |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | ≥ 8 |
| 2011 | 102 | ≥ 8 | ≥ 8 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2012 | 103 | ≥ 8 | ≥ 8 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2013 | 112 | ≥ 8 | ≥ 8 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2014 | 116 | ≥ 8 | ≥ 8 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2015 | 139 | ≥ 8 | ≥ 8 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| | | | | | Danofloxacin MIC frequency distribution (% of isolates) | | | | | | | | |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.015 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | ≥ 4 |
| 2011 | 102 | 1 | 1 | NA | 0 | 0 | 0 | 0 | 2 | 20.6 | 77.4 | 0 | 0 |
| 2012 | 103 | 1 | 1 | NA | 0 | 0 | 0 | 0 | 2 | 18.4 | 79.6 | 0 | 0 |
| 2013 | 112 | 1 | 1 | NA | 0 | 0 | 0 | 0 | 4.5 | 7.1 | 87.5 | 0.9 | 0 |
| 2014 | 116 | 1 | 1 | NA | 0.9 | 0 | 0.9 | 0 | 2.6 | 17.2 | 78.5 | 0 | 0 |
| 2015 | 139 | 1 | 1 | NA | 0 | 0 | 0 | 0 | 5.8 | 7.2 | 87 | 0 | 0 |
| | | | | | Enrofloxacin MIC frequency distribution (% of isolates) | | | | | | | | |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.008 | 0.016 | 0.03 | 0.06 | 0.12 | 0.25 | 0.5 | 1 | ≥ 2 |
| 2011 | 102 | 0.5 | 1 | NA | 0 | 0 | 0 | 0 | 0 | 2.9 | 56.9 | 40.2 | 0 |
| 2012 | 103 | 0.5 | 0.5 | NA | 0 | 0 | 0 | 0 | 0 | 2.9 | 87.4 | 9.7 | 0 |
| 2013 | 112 | 0.5 | 1 | NA | 0 | 0 | 0 | 0 | 0.9 | 5.4 | 63.4 | 30.3 | 0 |
| 2014 | 116 | 0.5 | 1 | NA | 0.9 | 0 | 0 | 0.9 | 4.3 | 1.7 | 82 | 10.3 | 0 |
| 2015 | 139 | 0.5 | 1 | NA | 0 | 0 | 0 | 0 | 4.3 | 5 | 77.7 | 13 | 0 |
| | | | | | Florfenicol MIC frequency distribution (% of isolates) | | | | | | | | |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 102 | 4 | 4 | 23.5 | 0 | 0 | 0 | 0 | 4.9 | 18.6 | 74.5 | 2 | 0 |
| 2012 | 103 | 4 | 4 | 14.5 | 0 | 0 | 0 | 0 | 1.9 | 12.6 | 83.5 | 2 | 0 |
| 2013 | 112 | 4 | 4 | 5.4 | 0 | 0 | 0 | 0 | 0 | 5.4 | 94.6 | 0 | 0 |
| 2014 | 116 | 4 | 4 | 11.2 | 0 | 0 | 0 | 0 | 0 | 11.2 | 88.8 | 0 | 0 |
| 2015 | 139 | 4 | 4 | 7.9 | 0 | 0 | 0 | 0 | 0 | 7.9 | 84.2 | 7.2 | 0 |
| | | | | | Penicillin MIC frequency distribution (% of isolates) | | | | | | | | |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | ≤ 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | ≥ 32 |
| 2011 | 102 | ≥ 32 | ≥ 32 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2012 | 103 | ≥ 32 | ≥ 32 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2013 | 112 | ≥ 32 | ≥ 32 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 2014 | 116 | ≥ 32 | ≥ 32 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | 98.3 |
| 2015 | 139 | ≥ 32 | ≥ 32 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 99.3 |

**Table 5:** Continued

| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tetracycline MIC frequency distribution (% of isolates) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | ≥ 64 |
| 2011 | 102 | 1 | 2 | NA | 4.9 | 42.2 | 38.2 | 8.8 | 4.9 | 0 | 1 | 0 | 0 |
| 2012 | 103 | 0.5 | 2 | NA | 7.8 | 51.5 | 29.1 | 4.8 | 4.8 | 0 | 1.9 | 0 | 0 |
| 2013 | 112 | 1 | 4 | NA | 0 | 6.3 | 75 | 8 | 8 | 0 | 2.7 | 0 | 0 |
| 2014 | 116 | 0.5 | 2 | NA | 0 | 59.5 | 25 | 12.1 | 2.6 | 0 | 0.9 | 0 | 0 |
| 2015 | 139 | 1 | 2 | NA | 0 | 45.3 | 44.6 | 7.9 | 1.4 | 0 | 0.7 | 0 | 0 |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tilmicosin MIC frequency distribution (% of isolates) | | | | | | | | |
| | | | | | ≤ 0.25 | 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | ≥ 64 |
| 2011 | 102 | 32 | ≥ 64 | NA | 0 | 0 | 0 | 0 | 0 | 2 | 14.7 | 68.6 | 14.7 |
| 2012 | 103 | 32 | 32 | NA | 0 | 0 | 0 | 0 | 1 | 1 | 13.6 | 77.6 | 6.8 |
| 2013 | 112 | 32 | ≥ 64 | NA | 0 | 0 | 0 | 0 | 0 | 4.5 | 9.8 | 63.4 | 22.3 |
| 2014 | 116 | 32 | ≥ 64 | NA | 0 | 0 | 0 | 0 | 0.9 | 6.9 | 8.6 | 56 | 27.6 |
| 2015 | 139 | 32 | ≥ 64 | NA | 0 | 0 | 0 | 0 | 0.7 | 5 | 2.9 | 48.2 | 43.2 |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | TMP-SMX MIC frequency distribution (% of isolates) | | | | | | | | |
| | | | | | ≤ 0.06 | 0.12 | 0.25 | 0.5 | 1 | 2 | 4 | 8 | ≥ 16 |
| 2011 | 102 | 8 | 8 | NA | 6.9 | 1.9 | 3.9 | 0 | 0 | 12.7 | 21.6 | 48 | 4.9 |
| 2012 | 103 | 8 | 8 | NA | 10.7 | 0 | 1 | 0 | 1.9 | 4.8 | 24.3 | 47.6 | 9.7 |
| 2013 | 112 | 8 | ≥ 16 | NA | 7.1 | 1.8 | 0 | 0 | 0 | 3.6 | 6.3 | 43.8 | 37.4 |
| 2014 | 116 | 8 | ≥ 16 | NA | 7.8 | 0 | 0.9 | 0 | 0.9 | 4.3 | 21.6 | 47.4 | 17.1 |
| 2015 | 139 | 8 | ≥ 16 | NA | 5 | 0 | 0 | 0 | 0.7 | 4.3 | 8.6 | 71.9 | 9.4 |
| Year | No. | $MIC_{50}$ (µg/mL) | $MIC_{90}$ (µg/mL) | %S | Tulathromycin MIC frequency distribution (% of isolates) | | | | | | | | |
| | | | | | ≤ 0.5 | 1 | 2 | 4 | 8 | 16 | 32 | 64 | ≥ 128 |
| 2011 | 102 | 8 | 16 | 100 | 0 | 0 | 2 | 2.9 | 54.9 | 40.2 | 0 | 0 | 0 |
| 2012 | 103 | 8 | 8 | 99 | 0 | 0 | 2.9 | 22.3 | 70.9 | 2.9 | 1 | 0 | 0 |
| 2013 | 112 | 8 | 8 | 99.1 | 0 | 0.9 | 4.5 | 19.6 | 71.4 | 2.7 | 0.9 | 0 | 0 |
| 2014 | 116 | 8 | 8 | 100 | 0 | 0.9 | 12.1 | 6.9 | 73.3 | 6.9 | 0 | 0 | 0 |
| 2015 | 139 | 8 | 16 | 100 | 1.4 | 2.2 | 2.9 | 3.6 | 71.2 | 18.7 | 0 | 0 | 0 |

* No. = the number of isolates tested per year; $MIC_{50}$ = antibacterial drug concentration that inhibits 50% of the bacterial population; $MIC_{90}$ = antibacterial drug concentration that inhibits 90% of the bacterial population; %S = the percentage of isolates that are susceptible to the antibacterial drug using Clinical and Laboratory Standards Institute (CLSI) criteria; NA = not applicable since there are no CLSI-approved clinical breakpoints for susceptibility in that swine respiratory disease pathogen; NT = not tested; vertical bold lines indicate the CLSI-approved breakpoint for susceptible, intermediate, and resistant in that swine respiratory disease pathogen; TMP-SMX = trimethoprim-sulfamethoxazole; numbers in the lowest concentration of the tested antibacterial drug range represent the percentage of isolates that had MICs less than or equal to the lowest drug concentration tested per year, while numbers above the highest antibacterial drug concentration represent the percentage of isolates that had MICs greater than the highest drug concentration tested that year. Percent MIC frequency rows may not add to 100% due to rounding.

to ceftiofur, enrofloxacin, and florfenicol, and high levels of susceptibility (> 90% to 100%) to ampicillin, penicillin, tilmicosin, and tulathromycin, with low levels of susceptibility (22.3% to 35.3%) to tetracycline for 855 *P multocida* isolates from 2011 to 2015. The $MIC_{90}$ values for ceftiofur (≤ 0.03 µg per mL), enrofloxacin (≤ 0.03 µg per mL), and florfenicol (0.5 µg per mL) have also remained well below the susceptible breakpoints since 2001.[4]

Numerous studies have been published on the susceptibility of *S suis* to antimicrobial agents.[19-21] Additionally, Callens et al[22] reported on the antimicrobial susceptibility to nine antimicrobial agents for *S suis* isolated from healthy pigs in which low rates of susceptibility (5%) were reported for tetracycline, and high rates of susceptibility were reported for florfenicol (99.7%) and enrofloxacin (99.7% ). El Garch et al[18] reported high susceptibility (96% to100%) to amoxicillin-clavulanate, ceftiofur, enrofloxacin, and florfenicol and 4% susceptibility to tetracycline when tested against 151 isolates of *S suis*. Susceptibility data from our 2001-2010 SRD surveillance program reported high rates of susceptibility (> 90% to 100%) to ceftiofur and florfenicol,[4] and this current report shows high levels of susceptibility (> 90% to 100%) to ampicillin, ceftiofur, and florfenicol, with low levels of susceptibility (0% to 1.3%) to tetracycline against 1201 *S suis* isolates from 2011 to 2015.

For *B bronchiseptica*, Dayao et al[14] reported 100% susceptibility to tulathromycin for 18 isolates, while El Garch et al[18] reported high susceptibility to amoxicillin-clavulanate (95.8%) and tulathromycin (99.2%) and lower susceptibility to florfenicol (52.5%) for 118 isolates. The inclusion of *B bronchiseptica* into this surveillance program did not occur until 2009. Three antimicrobial drugs used in this study have established CLSI clinical breakpoints for *B bronchiseptica* including ampicillin, florfenicol, and tulathromycin. For this study, 99% to 100% susceptibility to tulathromycin was observed, while no susceptibility (0%) to ampicillin and low susceptibility (5.4% to 23.5%) to florfenicol were observed against 572 *B bronchiseptica* isolates from 2011 to 2015.

A number of authors have highlighted the challenges of surveillance programs and the potential biases that may be encountered.[6,23,24] While there is no "gold standard" for evaluating the antimicrobial surveillance of animal pathogens, a report is available that offers guidance on areas in which harmonization can be achieved in veterinary antimicrobial surveillance programs with the intent of facilitating comparison of data among surveillance programs.[25] All surveillance studies still have certain biases and limitations to consider when interpreting susceptibility data. For this current study, 2940 clinical isolates were collected from 2011 to 2015 and analyzed, but this number of clinical isolates is still small when considering the number of cases of SRD in North America over the last 5 years. As the isolates in this current study originated from many veterinary diagnostic laboratories, the methods of sample selection, collection, and submission varied among laboratories. To help decrease regional sampling bias in this study, the number of isolates of a target species from any herd was restricted to one isolate during any quarter year period.[4] However, the number of isolates submitted by each participating laboratory was different per year, and not all enrolled laboratories may have actually submitted isolates for susceptibility testing. The design of the survey, including limits on the number of isolates collected within a given time period from a single herd and from a single diagnostic laboratory, can help reduce but not eliminate selection bias. The use of just two laboratories to perform the MIC testing minimized potential testing bias, and both laboratories adhered strictly to standard microbiological methods for veterinary susceptibility testing and quality-control standards published by CLSI. Finally, biases reported in other programs, such as a passive surveillance design, non-consideration in differences between livestock farm types and sizes, or prior treatment of animals with antibacterial agents, are acknowledged in this and other studies.[4,5] Furthermore, the lack of clinical breakpoints or interpretive criteria for certain antibacterial agents against pathogens to determine rates of susceptibility continue to be a limitation to veterinary surveillance. A greater collaborative effort among academic and industrial veterinary groups should be made to identify what gaps exist for available breakpoints and then establish CLSI-endorsed clinical breakpoints as long as a standardized approach is used.

The interpretation of MIC values from this study relies on clinical breakpoints to predict a potential susceptible, intermediate, or resistant outcome for use of an antibacterial agent to treat an infection.[8] The category of "susceptible" implies that an infection due to a bacterial pathogen may be susceptible to treatment with an antibacterial agent, taking into consideration the dosage regimen; the "intermediate" category implies that an infection due to a bacterial pathogen may be susceptible to treatment where the agent is physiologically concentrated and serves as a buffer zone against technical factors that may cause discrepancies in interpretation; the "resistant" category implies that resistant strains are not inhibited by the achievable concentrations of an antibacterial agent and resistance mechanisms are likely present within the pathogen.[8] In establishing veterinary-specific clinical breakpoints, a tripartite database, including minimal inhibitory concentration distribution data, pharmacokinetic-pharmacodynamic data, and clinical outcome data, are considered. It should be kept in mind that the purpose of antimicrobial susceptibility testing is not to mimic in vivo conditions, but to establish a method that provides reproducible results that may be correlated to clinical outcome, and that the in vitro antibacterial activity of an antimicrobial agent is only one component to consider for the likelihood of overall clinical efficacy in which pharmacokinetics and drug dosage also play a major role.[26] Additionally, other factors, such as health status of the animal, virulence factors of a pathogen, co-infections, stage of respiratory disease, and time point of antibacterial drug administration, among many other variables, must also be considered regarding clinical outcome by the attending veterinarian.[27]

The data presented from this current study, especially data that show a continued lack of susceptibility to certain antimicrobial agents such as tetracycline, should serve to underscore the importance of prudent use of these drugs when treating SRD. Although tetracycline has traditionally served as the "class representative" agent for in vitro susceptibility testing for veterinary tetracyclines, extrapolation of tetracycline susceptibility results may not necessarily be predictive of activity or clinical outcome for other tetracycline agents, such as oxytetracycline or chlortetracycline, due to differences in blood and lung-tissue concentrations and differences in bioavailability. Even though there are CLSI-established clinical breakpoints for tetracycline that were used in evaluating data in this study, it should be pointed out that these breakpoint values were derived partly from oxytetracycline pharmacokinetic data.[9]

The high levels of antimicrobial susceptibility observed in this study and others may be attributed to specific health management practices within swine herds, such as the "all-in, all-out" management practice system. This practice involves the commingling of pigs of similar age and weight, as well as group housing and pen cleaning between housing episodes, among other key components, and has been successful in combating the spread of certain infectious diseases.[28] Future studies may be able to determine if this management practice has an effect on antibiotic resistance changes over time, and if resistance reduction can be achieved through alternations in further enhanced housing and cleaning practices. Additionally, a pragmatic variation of the "all-in, all-out" model may represent an opportunity for other livestock practices to follow, especially since rates of antimicrobial resistance among cattle respiratory pathogens appear to be higher than those among swine respiratory pathogens.[4,29]

The results of this surveillance study using standardized susceptibility testing methods show high percentages of antimicrobial susceptibility among the major respiratory tract pathogens isolated from swine across the United States and Canada, except for tetracycline, and results from this 5-year SRD surveillance study are similar to those previously published.[4] This surveillance study continues to be useful in identifying the development of antimicrobial resistance among SRD target pathogens, which is crucial for the prudent use of antimicrobial agents in veterinary medicine.

Additionally, understanding the in vitro susceptibility of SRD pathogens isolated in the United States and Canada continues to be an important component of antimicrobial stewardship. Even though this study shows high rates of susceptibility for antimicrobial agents against SRD pathogens, public perceptions, as well as regulatory pressures, continue to drive the need for newer, alternative treatment options which may include novel antibacterial classes, re-evaluation of older or discontinued antibacterial agents, posology, and alternative approaches such as bacteriophages and peptides.[30]

## Implications

- Key antimicrobial agents approved for treatment of SRD in the United States and Canada have high rates of susceptibility for *A pleuropneumoniae, P multocida, S suis,* and *B bronchiseptica*.
- Under the conditions of this study, the lowest rates of susceptibility are seen with tetracycline against *A pleuropneumoniae, P multocida,* and *S suis,* and with ampicillin and florfenicol against *B bronchiseptica*.
- Continuous monitoring of antimicrobial susceptibility among swine pathogens provides up-to-date information about susceptibility trends for commonly used antimicrobial agents and is an important component of responsible use and antimicrobial stewardship.


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### Conflict of interest

Authors MTS, CL, LJ, LM, MKS, RM, SFK, RT, and JLW were employed by Zoetis; and authors DB and CM were employed by Microbial Research, Inc, at the time this study was being planned and performed.

## Disclaimer

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* Non-refereed references.

# Conversion tables

**Weights and measures conversions**

| Common (US) | Metric | To convert | Multiply by |
|---|---|---|---|
| 1 oz | 28.35 g | oz to g | 28.4 |
| 1 lb (16 oz) | 453.59 g | lb to kg | 0.45 |
| 2.2 lb | 1 kg | kg to lb | 2.2 |
| 1 in | 2.54 cm | in to cm | 2.54 |
| 0.39 in | 1 cm | cm to in | 0.39 |
| 1 ft (12 in) | 0.31 m | ft to m | 0.3 |
| 3.28 ft | 1 m | m to ft | 3.28 |
| 1 mi | 1.6 km | mi to km | 1.6 |
| 0.62 mi | 1 km | km to mi | 0.62 |
| 1 $in^2$ | 6.45 $cm^2$ | $in^2$ to $cm^2$ | 6.45 |
| 0.16 $in^2$ | 1 $cm^2$ | $cm^2$ to $in^2$ | 0.16 |
| 1 $ft^2$ | 0.09 $m^2$ | $ft^2$ to $m^2$ | 0.09 |
| 10.76 $ft^2$ | 1 $m^2$ | $m^2$ to $ft^2$ | 10.8 |
| 1 $ft^3$ | 0.03 $m^3$ | $ft^3$ to $m^3$ | 0.03 |
| 35.3 $ft^3$ | 1 $m^3$ | $m^3$ to $ft^3$ | 35 |
| 1 gal (128 fl oz) | 3.8 L | gal to L | 3.8 |
| 0.264 gal | 1 L | L to gal | 0.26 |
| 1 qt (32 fl oz) | 946.36 mL | qt to L | 0.95 |
| 33.815 fl oz | 1 L | L to qt | 1.1 |

**Temperature equivalents** (approx)

| °F | °C |
|---|---|
| 32 | 0 |
| 50 | 10 |
| 60 | 15.5 |
| 61 | 16 |
| 65 | 18.3 |
| 70 | 21.1 |
| 75 | 23.8 |
| 80 | 26.6 |
| 82 | 28 |
| 85 | 29.4 |
| 90 | 32.2 |
| 102 | 38.8 |
| 103 | 39.4 |
| 104 | 40.0 |
| 105 | 40.5 |
| 106 | 41.1 |
| 212 | 100 |

°F = (°C × 9/5) + 32
°C = (°F - 32) × 5/9

**Conversion chart, kg to lb (approx)**

| Pig size | Lb | Kg |
|---|---|---|
| Birth | 3.3-4.4 | 1.5-2.0 |
| Weaning | 7.7 | 3.5 |
| | 11 | 5 |
| | 22 | 10 |
| Nursery | 33 | 15 |
| | 44 | 20 |
| | 55 | 25 |
| | 66 | 30 |
| Grower | 99 | 45 |
| | 110 | 50 |
| | 132 | 60 |
| Finisher | 198 | 90 |
| | 220 | 100 |
| | 231 | 105 |
| | 242 | 110 |
| | 253 | 115 |
| Sow | 300 | 135 |
| | 661 | 300 |
| Boar | 794 | 360 |
| | 800 | 363 |

1 tonne = 1000 kg
1 ppm = 0.0001% = 1 mg/kg = 1 g/tonne
1 ppm = 1 mg/L

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Original research

# Average daily gain and the impact of starting body weight of individual nursery and finisher Ugandan pigs fed a commercial diet, a forage-based diet, or a silage-based diet

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## Summary

**Objectives:** To compare average daily gain (ADG) of Ugandan nursery and finisher pigs fed a commercial diet, a forage-based diet, or a silage-based diet, and to compare the cost effectiveness of the diets.

**Materials and methods**: Each pig was randomly assigned to the commercial diet, the forage-based diet, or the silage-based diet. Pigs were weighed every 3 weeks from 65 to 230 days of age. Growth was compared within and across diet on the basis of starting body weight (BW). The cost of feed per kg of BW gain was determined.

**Results:** As age and BW increased, mean BW variability increased in pigs fed the forage-based or silage-based diets and decreased in pigs fed the commercial diet. Starting BW was positively associated with ADG ($P < .01$). Average daily gain of nursery pigs fed the commercial diet was higher than that of pigs fed the forage-based and silage-based diets. At sufficient BW (≥ 11.9 kg), pigs fed the silage-based diet achieved ADG similar to that in pigs fed the commercial diet.

**Implications:** At sufficient BW (11 to 12 kg) pigs grow well on forage- or silage-based diets. If some ingredients are in surplus on farms, the forage- and silage-based diets are more cost effective than the commercial diet when pigs reach 8.5 kg BW. Interventions to improve weaning weights and provision of creep feed, and identification of nutrient-dense, digestible, palatable feedstuffs for development of low-cost balanced diets are needed in order to improve pig growth performance in East Africa.

**Keywords:** swine, average daily gain, forage, silage, East Africa

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**Resumen - Ganancia diaria promedio y el impacto del peso corporal inicial de cerdos individuales en destete y engorda de Uganda alimentados con una dieta comercial, una dieta a base de forraje, o una dieta a base de ensilado**

**Objetivos:** Comparar la ganancia diaria promedio (ADG por sus siglas en inglés) de cerdos Ugandeses de destete y crecimiento alimentados con una dieta comercial, una dieta a base de forraje, o una dieta a base de ensilado y comparar el costo efectividad de las dietas.

**Materiales y métodos:** Cada cerdo fue asignado aleatoriamente a la dieta comercial, la dieta a base de forraje, o la dieta a base de ensilado. Los cerdos se pesaron cada 3 semanas desde los 65 a los 230 días de edad. El crecimiento se comparó dentro y entre la dieta en base al peso corporal (BW por sus siglas en inglés) inicial. Se determinó el costo de alimento por kg de peso ganado.

**Resultados:** Conforme la edad y el peso, incrementó la variabilidad del peso promedio en cerdos alimentados con las dietas a base de forraje y ensilado y disminuyó en los cerdos alimentados con la dieta comercial. El peso inicial fue asociado positivamente con la ADG ($P < .01$). La ganancia diaria promedio de los cerdos en destete alimentados con dieta comercial fue más alta que la de los cerdos alimentados con las dietas a base de forraje y a base de ensilado. En un peso apto (≥ 11.9 kg), los cerdos alimentados con la dieta a base de ensilado lograron una ADG similar a la de los cerdos alimentados con la dieta comercial.

**Implicaciones:** En un peso apto (11 a 12 kg) los cerdos crecen bien en dietas en base a forraje o ensilado. Si existen algunos ingredientes extra en las granjas, las dietas basadas en forraje y ensilado son más costo efectivas que la dieta comercial cuando los cerdos alcanzan 8.5 kg de peso. Las intervenciones para mejorar los pesos al destete y el suministro de alimento a los lechones en maternidad, y la identificación de piensos densos en nutrientes, digestibles, apetecibles para el desarrollo de dietas balanceadas de bajo costo son necesarios para mejorar el desempeño del crecimiento del cerdo en África del Este.

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**Résumé – Gain moyen quotidien et impact du poids corporel initial de porcs en pouponnière et en finition en Ouganda nourris avec une diète commerciale, une diète à base de fourrage, ou une diète à base d'ensilage**

**Objectifs:** Comparer le gain moyen quotidien (GMQ) de porcs en pouponnière et en finition, en Ouganda, nourris avec une diète commerciale, une diète à base de fourrage, ou une diète à base d'ensilage et comparer l'efficacité des coûts de ces diètes.

**Matériels et méthodes:** Chaque porc fut assigné de manière aléatoire à l'une des trois diètes (commerciale, à base de fourrage, ou à base d'ensilage). Les porcs ont été pesés à chaque 3 semaines à compter de 65 jours d'âge jusqu'à 230 jours d'âge. La croissance a été comparée parmi et entre les diètes sur la base du poids corporel (PC) initial. Le coût en aliment par kg de gain de PC a été déterminé.

**Résultats:** À mesure que l'âge et le PC augmentaient, la variabilité du PC moyen augmentait chez les porcs nourris avec une diète à base de fourrage ou d'ensilage et diminuait chez les porcs nourris avec une diète commerciale. Le PC initial était positivement associé avec le GMQ ($P < 0,01$). Le GMQ des porcs en pouponnière nourris avec la diète commerciale était plus élevé que celui des porcs nourris avec les diètes à base de fourrage ou d'ensilage. À un PC adéquat (≥ 11,9 kg), les porcs nourris avec une diète à base d'ensilage avaient un GMQ similaire à celui des porcs nourris avec une diète commerciale.

**Implications:** À un PC adéquat (11 à 12 kg) les porcs se développent bien lorsque nourris avec un diète à base de fourrage ou d'ensilage. Si certains ingrédients sont en surplus sur les fermes, les diètes à base de fourrage et d'ensilage sont plus rentables que les diètes commerciales lorsque les porcs atteignent un PC de 8,5 kg. Des interventions pour améliorer le poids au sevrage et fournir de la moulée de démarrage, et l'identification d'aliments qui sont riches en nutriments, digestibles, et palatables pour le développement de diètes balancées à faible coût sont requises afin d'améliorer les performances de croissance des porcs en Afrique de l'Est.

Smallholder pig farmers in East Africa report that the high cost, poor quality, and lack of feed are key constraints to pig rearing.[1-5] Commercially prepared pig diets are beyond their financial means.[4,5] Pigs are fed carbohydrate-rich diets with little to no protein, which contributes to slow growth and poor farmer profit.[4-8] Well-balanced, cost-effective diets are needed to improve pig performance in East Africa. Fresh and ensiled locally available feedstuffs can be used to meet the nutrient requirements of pigs.[9-13] The objectives of this study were to compare average daily gain (ADG) of nursery and grower Ugandan pigs each fed one of three diets (commercial, forage-based, or silage-based) and to compare the cost effectiveness of the diets.

## Materials and methods

The study was reviewed and approved by the institutional animal care and use committees of the International Livestock Research Institute (ILRI), Nairobi, Kenya, and the University of Guelph, Guelph, Canada. The research site was a commercial pig operation in Masaka District, Central Region, Uganda.

### Diet formulation

The nutritional requirements of 8-kg to 65-kg pigs in Uganda were estimated using the methods reported previously.[14] Briefly, the dynamic nutrient requirement model for growing-finishing pigs[15] was converted into a static model to represent the use of daily intake of digestible energy (DE kcal per kg of dry matter [DM]) for body protein deposition (kg per day), body lipid deposition (kg per day), and maintenance for pigs weighing between 8 and 65 kg. The energy density in corn and soybean meal diets was used to establish nutrient requirements.[15] To determine the least-cost diet per unit of energy and other nutrients, diet costs were calculated at each 1% decrease in nutrient density, keeping ratios among the nutrient constraints and energy content constant. Diets were formulated at 80% of the reference nutrient density, since nutrients were optimal to improve pig performance, but still affordable to smallholder farmers. To limit fibrous feedstuffs, diet neutral detergent fibre (NDF) content was limited to 350 g per kg of DM, which is higher than that in conventional diets. However, local and cross-breed pigs may tolerate NDF at higher dietary levels than American or European breeds.[13,16] Salt and mineral-vitamin premix minimum constraints (3.9 and 1.5 g per kg of DM, respectively) were imposed per NRC recommendations. [15] Balanced low-cost diets (forage-based and silage-based) were formulated (Table 1) using methods previously described.[14]

### Sweet potato vine and tuber silage production

Sweet potato vines of mixed varieties and tubers of mixed orange and yellow flesh varieties were wilted on tarpaulins for 3 days, then chopped into 5- to 10-cm long pieces. Tubers were chopped into 2.5-$cm^3$ pieces. Six bunks (4.2 × 1.1 × 1.1 m) built with bricks and cement were lined with polythene and filled one at a time. Vines, tubers, and salt were placed in alternating layers (70%, 30%, 0.05% on an as-fed basis, respectively). The vine:tuber:salt ratio reflected reported optimal nutrient and pH results for silage in East Africa.[17] Each layer was compacted by hand-rolling with a heavy log, then was tightly wrapped with polythene for > 30 days before use. The appropriate amount of each ingredient (post wilting) was weighed and mixed, a 0.30-kg sample was collected for nutrient analysis, and then the diet was stored in uncovered 60-L plastic containers.

### Sample size

Sample size was calculated using a two-sample *t* test with 80% power to detect a significant difference in ADG of 0.20 kg at the 5% confidence level. Between-pig standard deviation (SD) of gain per day was estimated to be 0.25 kg. Twenty-five pigs per diet were required; therefore 30 pigs were randomly allocated to each diet group using a random number generator.

### Pre-study pig management

One hundred and ten pigs from 14 local smallholder farms, born within 3 days of each other, were enrolled in the study. At 10 days of age, pigs were individually ear-tagged and received 2 mL of a single product containing iron and vitamin $B_{12}$ by intramuscular injection (Bremer Pharma GMBh, Werkstr 42, 34414 Warburg, Germany). Males were castrated and birth dates were recorded. At 36 days of age, pigs received 300 μg per kg BW of ivermectin subcutaneously (V.M.D., Hoge Mauw 900, 2370 Arendonk, Belgium). At 56 days of age, all pigs arrived at the research farm and received 300 mg per kg BW of albendazole orally (Ashish Life Science PVT Ltd 213, Mumbai-53, India) and ivermectin as above.

### Pen management

Pens were labelled with a number and diet type, scraped daily, and washed weekly. Uneaten feed was weighed and discarded daily. One handful of chopped straw was put in each pen daily for environmental enrichment.

### Diets

Pigs were each fed one of three diets ad libitum three times daily. The three diets included a

**Table 1:** Compositions of diets (as-fed basis) used in a growth study of nursery and finisher pigs in Uganda

| | Forage-based diet* | | | Silage-based diet* | | |
|---|---|---|---|---|---|---|
| **Age (days)** | **65-107** | **108-167** | **199-230** | **65-107** | **108-140** | **146-230** |
| **Ingredient (%)** | | | | | | |
| Avocado (*Persea americana*); ripe, with peel, seed removed | 18.02 | 19.6 | 25.5 | 0.0 | 0.0 | 0.0 |
| Banana leaf (*Musa sapientum*); centre vein removed | 1.1 | 1.3 | 1.7 | 0.0 | 0.0 | 0.0 |
| Cassava leaf, blade, and axil (*Manihot esculenta*); wilted | 0.0 | 0.0 | 0.0 | 2.6 | 2.0 | 0.0 |
| Cottonseed meal | 0.0 | 1.4 | 1.8 | 1.3 | 1.3 | 1.7 |
| Jackfruit (*Artocarpus heterophyllus*); ripe, with peel and seeds | 39.9 | 16.8 | 21.9 | 20.8 | 25.8 | 22.7 |
| Maize bran | 0.0 | 4.1 | 9.5 | 0.0 | 0.0 | 12.4 |
| Papaya leaf (*Carica papaya*); wilted | 0.0 | 0.0 | 0.0 | 6.4 | 7.1 | 0.0 |
| Ground sun-dried fish (*Rastrineobola argentea*) | 7.5† | 2.2‡ | 3.1‡ | 4.4† | 2.0‡ | 2.7‡ |
| Sweet potato vine (*Ipomoea batatas*); wilted | 33.3 | 54.2 | 36.1 | 0.0 | 0.0 | 0.0 |
| Sweet potato vine and tuber silage (*Ipomoea batatas*) | 0.0 | 0.0 | 0.0 | 64.5 | 61.6 | 60.8 |
| Limestone | 0.19 | 0.10 | 0.14 | 0.0 | 0.0 | 0.0 |
| Common table salt | 0.12 | 0.10 | 0.14 | 0.09 | 0.09 | 0.13 |
| Vitamin and mineral premix§ | 0.05 | 0.04 | 0.07 | 0.04 | 0.06 | 0.06 |

* Non-compliance in diet formulation occurred when pigs were168 to 198 days of age. Data not presented.
† Pre-ground livestock-grade.
‡ Whole human-consumption grade ground at research site.
§ The premix provided the following per kg of complete feed (dry matter): vitamin A 15,000,000 IU; vitamin $D_3$ 2,000,000 IU; vitamin E 20,000 IU; vitamin $K_3$ 6000 mg; vitamin $B_1$ 1000 mg; vitamin $B_2$ 5000 mg; nicotinic acid 20,000 mg; pantothenic acid 16,000 mg; choline chloride 200,000 mg; biotin 110 mg; folic acid 1500 mg; manganese 40,000 mg; iron 150,000 mg; zinc 110,000 mg; copper 40,000 mg; cobalt 280 mg; iodine 1500 mg; selenium 120 mg.

**Table 2:** Analyzed nutrient compositions of study diets (% of DM) used in the growth study of nursery and finisher pigs in Uganda

| | Diet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forage-based | | | | Silage-based | | | | Commercial | | | |
| Pig age (days)* | 65-107 | 108-140 | 146-167 | 199-230 | 65-107 | 108-140 | 146-167 | 199-230 | 65-107 | 108-140 | 146-167 | 199-230 |
| DE (kcal/kg of DM)† | 1531 | 2333 | 2385 | 2688 | 1426 | 2277 | 2351 | 2309 | 2413 | 2681 | 2811 | 2499 |
| Ash | 21.2 | 11.9 | 11.9 | 9.4 | 19.6 | 12.0 | 12.6 | 12.0 | 10.1 | 9.3 | 8.6 | 11.4 |
| Crude protein | 17.9 | 18.8 | 18.4 | 15.7 | 18.9 | 17.9 | 16.9 | 14.4 | 15.9 | 17.2 | 17.3 | 18.4 |
| Neutral detergent fibre | 35.6 | 41.5 | 39.9 | 38.3 | 39.5 | 37.7 | 34.0 | 35.1 | 37.4 | 35.1 | 33.8 | 34.9 |
| Ether extract | 5.9 | 9.8 | 9.9 | 11.7 | 2.8 | 5.6 | 6.0 | 5.8 | 5.2 | 7.6 | 8.1 | 7.0 |
| Total calcium | 1.84 | 0.88 | 0.83 | 0.69 | 2.07 | 0.95 | 0.87 | 0.68 | 1.49 | 0.96 | 0.89 | 1.29 |
| Total phosphorus | 0.58 | 1.09 | 1.07 | 0.66 | 0.53 | 0.96 | 0.97 | 0.68 | 0.79 | 1.58 | 1.51 | 1.32 |
| Total Ca:total P | 3.17 | 0.81 | 0.78 | 1.05 | 3.91 | 0.99 | 0.90 | 1.00 | 1.89 | 0.61 | 0.59 | 0.98 |

* Non-compliance in diet formulation occurred when pigs were 168 to 198 days of age. Data not presented.
† Digestible energy (DE), estimated from analyzed nutrient composition of the diets according to NRC (2012).[15]
Ca = calcium; P = phosphorus; DM = dry matter.

commercially prepared diet labeled "Sow and weaner ration" (Ugachick Poultry Breeders, Kampala, Uganda); a forage-based diet; and a silage-based diet. It is important to note that the "Sow and weaner ration" is the only commercially-prepared ration available in Uganda, ie, grower and finisher rations are not available. Diet ingredient composition and analyzed nutrient composition are presented in Tables 1 and 2, respectively.

### Diet sampling

A 0.30-kg subsample of each diet type from a composite of the samples collected daily over a 4-week period was used for feed analysis. Each sample was weighed upon arrival, dried to constant weight at 60°C in a Leader oven model GP180CIA02501110 (Leader Engineering Heat Control, St Helens, Merseyside, United Kingdom), weighed again, then ground to pass through a 1-mm screen (Model CE96, United Kingdom). Samples were analyzed for DM,[18] crude protein,[19] ash and NDF,[20] phosphorus,[21] and calcium[22] at ILRI Laboratories, Addis Ababa, Ethiopia, and were analyzed for ether extract[19] at ILRI Laboratories, Hyderabad, India.

### Nursery study (65- to 140-day-old pigs)

Ninety 56-day-old pigs were each randomly assigned to one of three diets (commercial, forage-based, or silage-based) and to pens that were each blocked by one of two rooms, resulting in 10 pens per diet. All pigs were fed the commercial diet for a 7-day acclimation period, then introduced to their study diets over a 3-day period. At 65 days of age, the study began, when the pigs were fed only their study diets until they reached 140 days of age.

### Finisher study (146- to 167-day-old pigs and 199- to 230-day-old pigs)

The 140-day-old pigs remained in the same pen as for the nursery study, with the same pen mates. The same diet formulations were used, and all feeding and sampling methods remained the same. However, the diet assignment was changed. The total body weight (BW; kg) per pen and pen-level BW tertiles were determined. The two heaviest pens from each tertile within diet were assigned the same diet as during the nursery study. All other individual pens within each tertile were each randomly assigned to one of the three diets. Pigs assigned a new diet were introduced to it over a 7-day acclimation period. Nine replacement pigs were fed the commercial diet from 56 days of age until they were enrolled in the finisher study. Due to failure to procure required ingredients, non-compliance in diet preparation occurred when pigs were 168 to 198 days of age (data not presented).

### Pig weighing

Individual pigs were weighed and weights were recorded at Day 0 (65 days of age) and every 21 days following, using a model DV201 pig-weighing crate (Danvaegt, A/S, 8382 Hinnerup, Denmark) accurate to 1.0 kg.

### Statistical analysis

The unit of analysis was the individual pig. Each pig that died or was euthanized was replaced by a pig of approximately the same weight so that there were always three pigs in each pen. For the nursery study, the analyses included only the 81 pigs that began the trial at 65 days of age and lived to 140 days of age. For the finisher growth study, the pigs that were added partway through the nursery study were included in the analyses. Analysis of variance and Tukey's pairwise comparison were performed to determine if mean BW differed between diet treatments at the start of the nursery study (65-day-old pigs) and the start of the finisher study (146-day-old pigs). Individual pig ADG was regressed on diet type (commercial, forage-based, silage-based) and BW (kg) at the start of each weigh period as fixed effects, and on pen as a random variable using mixed multivariable linear regression. Pen was included in each model as a random variable to control for pen-level clustering. Linearity of the relationship between starting BW and ADG was assessed by testing the significance of a quadratic transformation of starting BW. A Wald's chi-square test was used to evaluate interactions between starting BW and diet to explore any potential effect on ADG. The coefficients from the linear regression represent the differences in ADG between the commercial diet and the forage- and silage-based diets after controlling for starting BW. Assumptions for the models were assessed by evaluating standardised residuals and plotting residuals against predicted ADG. Model fit with and without potential outliers was assessed using the Akaike's information criterion and the Bayesian information criterion. Mean starting BW (kg), ADG (kg per day), and SD of nursery and finisher pigs were determined (Table 3). Analysis of variance and Tukey's pairwise comparison were performed to determine if mean BW differed between diet treatments at the start of each weigh period (Table 3). The mean BW (kg), SD, and coefficient of variation (CV) within diet treatment were determined for nursery pigs at each weigh date (Table 4). All statistical analyses were performed using Stata 13.1 (StataCorp, College Station, Texas). Values of $P < .05$ were considered statistically significant.

### Comparative cost analysis

Using the price per kg of the commercial diet and of each ingredient from 199 to 230 days, ie, the most recent market price available prior to publication (Table 5), the cost of 1 kg of each diet was determined in two ways: first, assuming all ingredients were purchased, and second, assuming that the ingredients farmers could produce rather than purchase were free (ie, avocado, banana leaf, jackfruit, papaya leaf, sweet potato tubers and vines for use fresh or ensiled). Free ingredients were included in the diets, since others have shown that, in order to earn profits, East African pig farmers must feed diets containing some free ingredients.[8] Those costs of 1 kg of each diet were then used to calculate the cost of feed per kg of BW gain (Table 5).

## Results

### Diets

Ingredient compositions of the forage-based and silage-based diets are presented in Table 1. Ingredient composition of the commercial diet was unknown protected proprietary information. Diet nutrient compositions (analyzed) of all diets are presented in Table 2. Throughout the study, analyzed nutrient content was numerically different from estimated pig requirements and estimated values for diets. Due to high analyzed ash and NDF content, final DE in diets, determined by nutrient analysis, was numerically lower than the expected calculated DE that was based on the assumed nutrient contents of individual ingredients, especially from 65 to 86 days of age. When pre-ground sun-dried fish and unripe avocado were replaced with higher quality whole dried fish and ripe and overripe avocado, respectively, lower ash content and higher ether extract resulted in numerically higher calculated DE content, determined by analyzed diet nutrient contents. None of the diets provided the estimated DE requirement. The DE content of the commercial diet was numerically higher than the DE content of the forage- and silage-based diets from 65 to 167 days of age. From 199 to 230 days of age, the DE content of

**Table 3:** Mean starting body weight (BW; kg), mean average daily gain (ADG; kg/day), and standard deviation (SD) of nursery pigs (65-140 days old) and finisher pigs (146-230 days old)*

| | Commercial diet | | | Forage-based diet | | | Silage-based diet | | |
|---|---|---|---|---|---|---|---|---|---|
| Pig age (days) | Starting BW (kg) | ADG (kg/day) | SD (kg) | Starting BW (kg) | ADG (kg/day) | SD (kg) | Starting BW (kg) | ADG (kg/day) | SD (kg) |
| 65-86 | 6.8[a] | 0.201 | 0.0816 | 7.0 [a] | 0.021 | 0.0372 | 6.7[a] | 0.021 | 0.0461 |
| 87-107 | 11.1[a] | 0.405 | 0.0969 | 7.5[b] | 0.045 | 0.0371 | 7.1[b] | 0.077 | 0.0688 |
| 108-127 | 19.6[a] | 0.460 | 0.1392 | 8.4[b] | 0.118 | 0.0519 | 8.7[b] | 0.153 | 0.1050 |
| 128-140 | 29.2[a] | 0.264 | 0.2017 | 10.9[b] | 0.160 | 0.1364 | 11.9[b] | 0.234 | 0.1687 |
| 146-167 | 24.1[a] | 0.552 | 0.1710 | 21.4[a] | 0.116 | 0.0953 | 20.7[a] | 0.318 | 0.1309 |
| 199-209 | 52.6[a] | 0.744 | 0.1973 | 31.2[b] | 0.494 | 0.2109 | 38.7[b] | 0.713 | 0.1623 |
| 210-230 | 60.0[a] | 0.604 | 0.1385 | 36.2[b] | 0.336 | 0.1411 | 45.8[c] | 0.504 | 0.1369 |

* Non-compliance in diet formulation occurred when pigs were 168 to 198 days of age. Data not presented.
[a,b,c] Values within a row with differing superscripts are significantly different ($P < .05$; analysis of variance and Tukey's pairwise comparison).

**Table 4:** Coefficient of variation (CV), within diet treatment, of bodyweight (BW; kg) of nursery pigs at 65, 86, 107, 127, and 140 days of age

| | Commercial diet | | Forage-based diet | | Silage-based diet | |
|---|---|---|---|---|---|---|
| Pig age (days) | Mean BW (kg) (SD) | CV | Mean BW (kg) (SD) | CV | Mean BW (kg) (SD) | CV |
| 65 | 6.8 (2.12) | 0.31 | 7.0 (2.21) | 0.31 | 6.7 (1.91) | 0.29 |
| 86 | 11.1 (3.43) | 0.31 | 7.5 (2.58) | 0.34 | 7.1 (2.48) | 0.35 |
| 107 | 19.6 (4.79) | 0.25 | 8.4 (3.08) | 0.37 | 8.7 (3.69) | 0.42 |
| 127 | 29.2 (6.55) | 0.22 | 10.9 (3.85) | 0.35 | 11.9 (5.41) | 0.45 |
| 140 | 32.6 (7.48) | 0.23 | 13.0 (5.00) | 0.38 | 15.0 (6.51) | 0.43 |

SD = standard deviation.

**Table 5:** Cost of feed* per kg of weight gain (US$) for commercial, forage-, and silage-based diets according to age

| Age (days) | Commercial diet | FB buy all | FB some free | SB buy all | SB some free |
|---|---|---|---|---|---|
| 65 | 0.97 | 5.17 | 2.48 | 4.55 | 2.11 |
| 107 | 1.29 | 2.29 | 1.10 | 1.98 | 0.92 |
| 127 | 2.11 | 1.31 | 0.63 | 1.66 | 0.77 |
| 146 | 2.91 | 1.30 | 0.62 | 1.39 | 0.65 |
| 199 | 3.04 | 1.59 | 0.76 | 1.51 | 0.70 |

* At the following ingredient cost per kg as-fed basis (US$): avocado 0.11; banana leaf 0.12; cottonseed meal 0.42; jackfruit 0.11; maize bran 0.14; human grade whole sun-dried fish 2.04; sweet potato vine 0.12; papaya leaf 0.12; sweet potato vine and tubers for silage 0.12; limestone 0.03; salt 0.27; mineral and vitamin pre-mix 4.50.
FB = forage-based diet; SB = silage-based diet.

the commercial diet was numerically lower than that of the forage-based diet and higher than that of the silage-based diet.

### Mean BW in each 3-week growth period

Mean BW did not differ between diet treatments at the start of the nursery study (65 days) ($P > .05$) or the start of the finisher study (146 days) ($P > .05$) (Table 3).

Mean BW of pigs differed between the commercial diet and the forage-based diet, and between the commercial diet and the silage-based diet, at the start of all other growth periods ($P < .05$) (Table 3). Mean BW differed between all diet treatments at 210 days ($P < .05$) (Table 3).

### Average daily gain of nursery pigs (65 to 140 days of age)

On the basis of the regression analysis, when controlling for starting BW for the first three 3-week growth periods in the nursery phase (65 to 127 days of age), ADG of pigs fed the forage-based diet was lower by 0.176 (± 0.0172), 0.306 (± 0.0181) and 0.196 (± 0.0181) kg per day than ADG of pigs fed the commercial diet ($P < .001$), respectively, in each 3-week weighing period. Similarly, ADG of pigs fed the silage-based diet was 0.181 (± 0.0165), 0.269 (± 0.0181), and 0.163 (± 0.0399) kg per day lower than ADG of pigs fed the commercial diet ($P < .001$), respectively, in each 3-week weighing period. For every 1-kg increase in starting BW, ADG increased by 0.012 (± 0.003), 0.015 (± 0.002), 0.013 (± 0.003), and 0.009 (± 0.003) kg per day, for the four 3-week growth periods, respectively ($P < .001$).

### Average daily gain of finisher pigs (146 to 230 days of age)

From 146 to 167 days of age, when controlling for starting BW, ADG of pigs fed the commercial diet was 0.424 (± 0.0350) and 0.221 (± 0.0372) kg per day higher, respectively, than ADG of pigs fed the forage-based and silage-based diets ($P < .05$). From 209 to 230 days of age, when controlling for starting BW, ADG of pigs fed the commercial diet was 0.186 (± 0.0420) kg per day higher than that of pigs fed the forage-based diet ($P < .001$). For every 1-kg increase in starting BW, ADG increased by 0.004 (± 0.0012), 0.008 (± 0.0012), and 0.004 (± 0.0009) kg per day for the three 3-week growth periods of finisher pigs, ($P = .001$, $P < .001$, and $P < .001$, respectively).

### Variability in mean BW of nursery pigs

Variability (coefficient of variation; CV) in mean BW increased with age in pigs fed the forage-based and silage-based diets, but decreased with increasing age in pigs fed the commercial diet (Table 4). The CV of pigs fed the commercial diet was highest in 65- and 86-day-old pigs and lower in heavier, older pigs. The CVs of pigs fed the forage-based and silage-based diets were lowest in 65- and 86-day-old pigs and higher in older pigs.

### Comparative cost analysis

The cost of feed per kg of weight gain (US$) for each of the three diets when all ingredients were purchased or some ingredients were free is presented in Table 5. The cost per kg of weight gain of pigs fed the commercial diet was less than the cost per kg of weight gain of pigs fed the forage-based and silage-based diets when pigs weighed < 10.9 and < 11.9 kg BW, respectively. However at BW ≥ 10.9 and ≥ 11.9 kg, the cost per kg of weight gain of pigs fed the commercial diet was more than the cost per kg of weight gain of pigs fed the forage-based and silage-based diets.

When some ingredients were free, the cost per kg of weight gain of pigs fed the commercial diet was less than the cost per kg of weight gain of pigs fed the forage- and silage-based diets when pigs weighed < 8.4 and < 8.7 kg BW, respectively (tables 4 and 5). At BW ≥ 8.4 and ≥ 8.7 kg, the cost per kg of weight gain of pigs fed the commercial diet was more than the cost per kg of weight gain of pigs fed the forage-based and silage-based diets, respectively, when some ingredients were free (tables 4 and 5).

## Discussion

The results of this study show that East African farmers can improve pig growth performance by feeding forage- and silage-based diets. Empirical studies characterizing the ADG of pigs raised under smallholder management conditions (wherein pigs are tethered to graze on grass or roam free and scavenge) in Uganda have not been done. Pigs at mean BW ≥ 10.9 and ≥ 8.7 kg, fed the forage- or silage-based diet in this study, respectively, or fed the commercial diet, had higher ADG than pigs raised by smallholder farmers in Kenya (0.130 kg per day) under management practices similar to those observed in Uganda.[4,5,7]

The weaning weights of local breeds of pigs reported elsewhere in the tropics (4.87 ± 0.28 kg at 56 days of age;[23] 5.6 to 7.4 kg at 93 to 117 days of age[24]) were similar to the starting BW of pigs enrolled in this study.

Factors contributing to low ADG include introduction of a novel diet that potentially caused transient gastrointestinal hypersensitivity,[25] genotype, the composition and nutrient content of the diet, and the pigs' limited feed intake and digestive capacity for fibrous feeds due to age and size.

The composition and nutrient content of the diets may have contributed to low ADG. Given that the energy density of the forage- and silage-based diets was 70% to 80% of the energy density in the NRC[15] reference corn and soybean meal diets, and the high ash content, especially during the nursery phase, it is unlikely that pigs fed the forage- and silage-based diets consumed sufficient nutrients to reach their genetic growth potential. Although the energy density was reduced in an effort to increase the likelihood that Ugandan smallholder farmers could afford to adopt the forage- and silage-based diets, it is a limitation of this study. Future research is needed to investigate the growth of Ugandan pigs fed diets containing 100% of the nutrient density of NRC[15] reference corn and soybean meal diets.

In commercial settings, nutrient-dense, highly-digestible diets comprising oils, plasma, milk and fishmeal products, and feed additives are formulated to enable young pigs to maximize nutrient intake and potential growth performance.[15,25] However, these ingredients were not available to East African smallholder farmers and commercial creep feed was not available for purchase. The diets studied here contained more NDF and less estimated DE than the estimated amount required by pigs to achieve maximum growth.[14] Others reported that feeding fibrous feeds is cost-effective for pigs > 50 kg BW because pigs' ability to digest fibre increases with age.[26] However, for young growing pigs, dietary fibre provides little or no energy, and the digestibility of energy and nutrients are reduced as dietary fibre content increases.[27] As previous research[28] suggests, pigs may have adapted to fibrous feed through ongoing exposure to the study diets, and their ability to digest dietary fibre may have improved with increased age and BW. This may have been reflected in the higher ADG of finisher pigs compared

to nursery pigs and the relative improvement of ADG in the forage- and silage-based diets compared to the commercial diet. From 65 to 107 days of age the wide calcium:phosphorus ratio across diets may have contributed to low ADG. As previous studies suggest, a wide calcium:phosphorus ratio lowers the absorption of phosphorous which results in slower growth.[15,29]

Low starting BW of pigs enrolled in this study may have resulted in low feed intake and consequently low ADG, as others have discussed.[23] Others estimated that ad libitum feed intake is influenced by BW and diet digestibility as follows: 0.013 × BW in kg ÷ (1 – digestibility).[30] This estimation demonstrates the impact that BW and diet digestibility can have on feed intake and consequently on ADG. Others[31] reported that higher feed intake in the period after weaning increases ADG of nursery pigs and ultimately in the finisher phase.

The higher ADG of heavier (≥ 10.9 and ≥ 11.9 kg) nursery pigs fed the forage- and silage-based diets, respectively, than that of lighter nursery pigs indicates the commercial diet was more suitable than the forage- and silage-based diets for small nursery pigs. Moreover, the high CV of mean BW and increase in CV with increased age and BW in pigs fed the forage- and silage-based diets indicates there were heavier pigs fed the forage- and silage-based diets that grew well and small pigs that did not grow well, and that pigs at 65 days of age can grow when fed the forage- and silage-based diets if the starting BW is sufficiently large.

It was more cost effective to feed the commercial diet while pigs weighed < 10.9 and < 11.9 kg BW (forage- and silage-based diets, respectively). In larger pigs (≥ 10.9 and ≥ 11.9 kg BW, respectively) the less expensive forage- and silage-based diets were cost effective. Similarly others[32] reported that as weaning weight increased, the cost per 100 kg of pig sold decreased, and income over cost increased. Although it is cost effective to feed a forage-based diet when pigs reach 8.4 kg if some ingredients are free, given the low ADG of pigs fed the forage-based diet at that BW, feeding a forage-based diet to such small pigs is not recommended. Feeding a commercial diet to newly weaned pigs, and then feeding forage- or silage-based diets to finisher pigs, is recommended. Commercial diets provide the least cost per kg BW gain in newly weaned pigs, but heavier, older pigs can be fed the more affordable forage- and silage-based diets, and achieve good growth performance.

Forage- and silage-based diets may be more accessible than commercial diets for resource-poor smallholder farmers. Resource-poor smallholder farmers may be able to afford the cost of making forage- and silage-based diets, spent in small increments over time when purchasing small amounts of ingredients, and growing some of the ingredients themselves. Purchasing a 70-kg bag of commercial diet may be prohibitively expensive. Purchasing it collectively as a farmer group and dividing it among group members to feed small, newly weaned pigs is recommended. The results of this study indicate that forage- and silage-based diets are not suitable for the smallest nursery pigs. Nursery pigs should be fed a commercial diet until they reach sufficient BW (10.9 and 11.9 kg for forage- and silage-based diets, respectively), to consume and digest sufficient quantities of high fibre, cost-effective diets. Finisher pigs can have higher ADG than that of similar pigs raised under smallholder management conditions, when fed these balanced forage- and silage-based diets that are less expensive than commercial diets. Moreover, finisher pigs can achieve similar ADG to those fed a commercial diet once they achieve sufficient BW.

Smallholder pig farmers should be encouraged to wean only the heaviest pigs and to provide a commercial diet to lightweight nursery pigs until they reach 10.9 and 11.9 kg, then use forage- or silage-based diets, respectively.

## Implications

- Cost-effective balanced forage- and silage-based diets can be made by smallholder farmers in East Africa to enhance growth of finisher pigs.
- It is less expensive to feed small nursery pigs a commercial diet until they achieve sufficient BW (10.9 and 11.9 kg) before feeding forage-based and silage-based diets, respectively.
- If some ingredients are in surplus on East African farms, forage- and silage-based diets are more cost effective than a commercial diet when the pigs reach 8.5 kg BW.
- Nutrient-dense, digestible, palatable feedstuffs to improve growth of newly weaned pigs should be identified and their nutrient content characterized for development of low-cost balanced diets.
- Interventions related to improving weaning weights and provision of creep feed are needed in order to improve pig growth performance.


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### Conflict of interest

None reported.

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Original research

# Effect of direct-fed microbial *Bacillus subtilis* C-3102 on enteric health in nursery pigs after challenge with porcine epidemic diarrhea virus

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## Summary

**Objective:** To examine the effects of feeding *Bacillus subtilis* C-3102 at the target inclusion rates of 0 colony forming units (CFU) per g, 500,000 CFU per g, and 1 million CFU per g on intestinal health in weaned pigs after challenge with porcine epidemic diarrhea virus (PEDV).

**Materials and methods:** A two-by-three factorial design was conducted, composed of three experimental diets and PEDV or sham challenge. Sixty 14-day-old pigs, negative for PEDV by quantitative real-time reverse transcription polymerase chain reaction (PCR) and negative by PCR for porcine reproductive and respiratory syndrome virus, were randomly allocated into six treatment groups with 10 pigs per group. Pigs were housed in groups of five in solid-floor pens. Treatment diets were fed for a total of 23 days, including 19 days before and 4 days after PEDV challenge or sham challenge by oral gavage.

**Results:** Pathological changes associated with PEDV were significantly less severe in challenged treatment groups that received *B subtilis* C-3102 than in the group that received no *B subtilis* treatment. There were no significant differences in small intestinal length, ratio of small intestinal weight to body weight, colon dry matter content, average daily gain, or fecal scoring between any of the six treatment groups.

**Implication:** Under the conditions of this study, treatment with *B subtilis* C-3102 in nursery pigs challenged with PEDV is associated with better enteric health than in pigs not treated with *B subtilis* C-3102.

**Keywords:** swine, porcine epidemic diarrhea virus, direct-fed microbials, *Bacillus subtilis*

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**Resumen - Efecto de la alimentación directa microbiana, *Bacillus subtilis* C-3102, en la salud entérica en cerdos de destete después del reto con el virus de la diarrea epidémica porcina**

**Objetivo:** Examinar los efectos de la alimentación con el *Bacillus subtilis* C-3102 en la índices meta de inclusión de 0 unidades formadoras de colonia (CFU por sus siglas en inglés) por g, 500,000 CFU por g, y 1 millón de CFU por g en la salud intestinal en cerdos destetados después del reto con el virus de la diarrea epidémica porcina (PEDV).

**Materiales y métodos:** Se condujo un diseño factorial de dos por tres, compuesto de tres dietas experimentales y PEDV o reto falso. Sesenta cerdos de 14 días de edad, negativos al PEDV por medio de la reacción cuantitativa en tiempo real en cadena de la polimerasa con transcriptasa inversa cuantitativa en tiempo real (PCR por sus siglas en inglés) y negativa por medio de la PCR al virus del síndrome reproductivo y respiratorio porcino (PRRSV), se distribuyeron aleatoriamente en seis grupos de tratamiento con 10 cerdos por grupo. Los cerdos fueron alojados en grupos de cinco animales en corrales de piso sólido. Se alimentaron con las dietas tratamiento por un total de 23 días, incluyendo 19 días antes y 4 días después del reto de PEDV o reto falso por medio de alimentación oral forzada.

**Resultados:** Los cambios patológicos asociados con el PEDV fueron significativamente menos severos en los grupos retados y con tratamiento que recibieron *B subtilis* C-3102 que en el grupo que no recibió tratamiento con *B subtilis*. No hubo diferencias significativas en la longitud del intestino delgado, relación del peso del intestino delgado con el peso corporal, contenido de materia seca del colon, ganancia diaria promedio, o puntaje fecal entre cualquiera de los seis grupos de tratamiento.

**Implicacione:** Bajo las condiciones de este estudio, el tratamiento con *B subtilis* C-3102 en cerdos de destete retados con el PEDV se asocia con mejor salud entérica que en cerdos no tratados con *B subtilis* C-3102.

**Résumé - Effet de l'administration orale de *Bacillus subtilis* C-3102 sur la santé entérique de porcelets en pouponnière suite à une infection avec le virus de la diarrhée épidémique porcine**

**Objectif:** Examiner les effets de l'administration orale de *Bacillus subtilis* C-3102 à la dose cible d'inclusion de 0 unité

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formatrice de colonie (UFC) par g, 500,000 UFC par g, et 1 million UFC par g sur la santé intestinale de porcelets sevrés suite à une infection défi avec le virus de la diarrhée épidémique porcin (VDEP).

**Matériels et méthodes:** Une étude avec un plan factoriel de 2 × 3 a été menée, composé de trois diètes expérimentales et une infection défi avec VDEP ou une infection simulée. Soixante porcs âgés de 14 jours, négatifs pour le VDEP par réaction d'amplification en chaîne quantitative (PCR) en temps réel avec la polymérase réverse et négatif par PCR pour le virus du syndrome reproducteur et respiratoire porcin (VSRRP), ont été répartis de manière aléatoire en six groupes de traitement de 10 porcs par groupe. Les porcs étaient logés en groupe de cinq porcs dans des parcs avec des planchers pleins. Les diètes ont été données aux groupes sous traitement pour un total de 23 jours, 19 jours avant et 4 jours après le challenge avec le VDEP ou l'infection simulée par gavage oral.

**Résultats:** Les changements pathologiques associés avec le VDEP étaient significativement moins sévères dans les groupes infectés ayant reçu *B subtilis* C-3102 comparativement aux groupes n'ayant pas reçu de traitement avec *B subtilis* C-3102. Il n'y avait aucune différence significative dans la longueur du petit intestin, le ratio du poids du petit intestin sur le poids corporel, le contenu en matière sèche du côlon, le gain moyen quotidien, ou le pointage fécal entre les six groupes de traitement.

**Implication:** Dans les conditions de la présente étude, le traitement avec *B subtilis* C-3102 de porcs en pouponnière infectés avec VDEP est associé avec une meilleure santé entérique que chez des porcs non traités avec *B subtilis* C-3102.

Porcine epidemic diarrhea virus (PEDV) was first detected in North America in April 2013 and since then has been diagnosed in over 30 US states, with more than 9000 confirmed cases.[1] It is well understood that PEDV affects intestinal health by producing atrophic enteritis through viral destruction of enterocytes.[1,2] Infected suckling and nursery pigs experience a maldigestive and malabsorptive diarrhea resulting in acute dehydration, and increased risk of septicemia due to decreased intestinal barrier functions. The severity of clinical signs is age dependent, with piglets less than 7 days of age demonstrating the most severe diarrhea and mortality rates.[1,2] Many swine production groups and stakeholders are interested in products that mitigate clinical signs and reduce intestinal pathology associated with PEDV. In addition to biologics and supportive fluid therapy, direct-fed microbials (DFMs) may present an alternative option to supportive therapy for PEDV-infected pigs. Direct-fed microbials, which are readily accessible to producers and easily incorporated into feed rations for adult and growing animals, have been investigated in the food-animal literature for their effects in improving intestinal health, feed efficiency, and meat quality, and modifying fecal consistency.[3,4] Targeted studies[5,6] have investigated the effects of DFMs on pathogen shedding and mitigating clinical signs caused by enteric pathogens, including *Salmonella* serovars and *Escherichia coli.* Common commercially available DFM products are strain specific and include yeasts and (or) bacteria, specifically *Bacillus* species and (or) *Lactobacillus* species. To date, we have been unable to find publically available peer-reviewed literature describing the effects of DFMs on intestinal health and pathology following challenge with or exposure to PEDV. As PEDV is a contemporary pathogen with several well developed challenge models, an assessment of the utility of DFMs in mitigating the effects of the disease was warranted and relevant to modern pig production.[3,7,8]

The focus of this study was on *Bacillus subtilis* C-3102 (Calsporin; Calpis Co Ltd, Japan and Quality Technology International, Huntley, Illinois), which is a gram-positive, catalase-positive, rod-shaped obligate aerobe that is stable in extreme environmental conditions.[9] It has a history of use in swine since 1981 and is manufactured as a commercial product available to the US swine industry.[10]

The objective of this study was to examine the effects on intestinal health and pathology of feeding *B subtilis* C-3102 prior to and during a PEDV challenge in weaned pigs. The targeted inclusion rates studied were 0 colony-forming units (CFUs) per g, 500,000 CFUs per g, and 1 million CFUs per g.

## Material and methods

This study was approved by the Iowa State University Institutional Animal Care and Use Committee.

### Animals and housing

Sixty 14-day old, high health status barrows (30) and gilts (30) were sourced from a private commercial provider in Iowa. Fourteen-day-old weaned piglets were selected to ensure that pigs would be sufficiently young at PEDV inoculation to experience clinical signs, and because suckling pigs would not have substantial feed intake while on the sow. Pigs and their dams had no history of PEDV or porcine deltacoronavirus exposure or clinical signs and were considered naive to these pathogens. Pigs were housed at the Iowa State University Laboratory Animal Resources Facility in 12 different rooms, five pigs per room, with two rooms for each treatment group. The rooms had solid floors, and each contained one water nipple and feeder. Pigs were fed ad libitum in a plastic pan-style feeder with 61 cm of tray length divided into three feeding spaces. Gruel feed was offered for the first 3 days of the study to ease the transition from milk to solid food. Floor space per animal met the requirements set in the Guide for the Care and Use of Agricultural Animals in Research and Teaching.[11]

### Study design

**Treatment allocation.** Upon arrival, pigs were each weighed and given a uniquely numbered plastic livestock ear tag placed in the right ear (Allflex, Dallas, Texas). Pigs were randomized to treatment groups and to individual rooms using the random number generator function in Microsoft Excel (Microsoft, Redmond, Washington). The 60 pigs were each randomly allocated to one of the six treatment groups (Table 1), with 10 pigs per treatment group (five barrows and five gilts).

This was a 2 × 3 factorial design involving three experimental diets and PEDV or sham challenge. The experimental diets were standard, commercially prepared, antibiotic-free nursery pig diets containing *Bacillus subtilis* C-3102 (Calsporin at 0, 500,000, or 1 million CFUs per g). Groups were challenged with either PEDV-positive or PEDV-negative cell-culture fluids by oral gastric gavage. Table 1 displays the six treatment groups represented in this design. Pigs were acclimated to the research facilities and solid feed for 3 days. The study diets were then fed for 19 days and pigs were inoculated with PEDV-positive or PEDV-negative cell-culture fluid on day 22. On the basis of the manufacturer's recommendations, optimal gastrointestinal effect was anticipated after feeding for 14 to 21 days, which thus was selected as the targeted duration of feeding before inoculation with PEDV.

Four days after inoculation (day 26), pigs were euthanized and necropsied. The pigs remained on the treatment diets up to and

**Table 1:** Pigs fed *Bacillus subtilis* C-3102 at one of three concentrations in the feed for 19 days were then administered, by gavage, cell culture either positive (three groups) or negative (three groups) for porcine epidemic diarrhea virus (PEDV)*

| Treatment group | Inoculum† | Diet treatment |
|---|---|---|
| 1 | PEDV-negative cell culture | None |
| 2 | PEDV-negative cell culture | *B subtilis* C-3102, 500,000 CFU/g |
| 3 | PEDV-negative cell culture | *B subtilis* C-3102, 1,000,000 CFU/g |
| 4 | PEDV-positive cell culture | None |
| 5 | PEDV-positive cell culture | *B subtilis* C-3102, 500,000 CFU/g |
| 6 | PEDV-positive cell culture | *B subtilis* C-3102, 1,000,000 CFU/g |

* 2 × 3 factorial design with 10 pigs randomly allocated to each dietary treatment group for a total of 60 pigs. Pigs weaned at 14 days of age were each fed *B subtilis* C-3102 (Calsporin; Calpis Co Ltd, Japan and Quality Technology International, Huntley, Illinois) for 19 days at one of three concentrations in the feed. On day 20 of feeding treatment diets, pigs received cell culture either positive or negative for PEDV by oral gavage. Four days after inoculation, pigs were euthanized by captive bolt and intestinal samples were collected.

† PEDV in cell culture was confirmed by quantitative real-time reverse transcription polymerase chain reaction testing.
CFUs = colony-forming units.

including the day of necropsy, totaling 23 days on the experimental diets.

## Pre-trial processing

On day 1 of the study, blood and fecal swabs were collected from each pig. Whole blood was collected by jugular venipuncture into a serum separator tube. Whole blood was centrifuged at 2000*g* for 10 minutes and serum was poured into plastic snap cap 5-mL serum tubes. Polyester-tip swabs were used to collect fecal samples. Swabs were then placed in 1 mL of sterile phosphate buffered saline (PBS) in a 5-mL snap cap tube. Serum and fecal samples were submitted to the Iowa State University Veterinary Diagnostic Laboratory (ISU VDL). The following assays were performed: PRRSV polymerase chain reaction (PCR)[12] was performed on serum samples pooled in groups of five. Additionally, PEDV[13] and PRRSV[12] enzyme-linked immunosorbent assays (ELISAs) were performed individually on serum samples. Fecal swabs were pooled in groups of five, and PEDV PCR[1,8] was performed on each pool. Pigs included in the trial did not consume water or feed with antibiotics for at least 7 days prior to the beginning of the trial, and had no prior injectable antibiotic treatments before the trial start date.

## Feed and water

Heartland Co-op (Waukee, Iowa) provided three custom grind and mix diets for the trial (*B subtilis* C-3102 at 0, 500,000, and 1 million CFU per g). The diets contained no antibiotics and met the National Research Council nutrition requirement for pigs.[14] The diets were produced at the mill in 453-kg batches. One 22.7-kg bag of *B subtilis* C-3102 (Calsporin 2.0B lot 190588) containing 412.3 billion CFU per kg of *B subtilis* C-3102, guaranteed analysis, was supplied to the feed mill and incorporated into the rations as per label instructions for each given concentration. The three rations were then processed into 22.7-kg bags labeled with the corresponding *B subtilis* C-3102 concentration. The feed was stored in bins with locking lids in each room. Correct diet allocation to each study room was verified by two people, independently, each day. Commercial nursery phase-one starter pellets without *B subtilis* C-3102 or antibiotics were fed during the first 3 days of the acclimation period. After the acclimation period, the pigs were started on the *B subtilis* C-3102 diets ad libitum and continued on these diets for the remainder of the trial. Daily feed and water samples were collected from each room and stored at -20°C for further analysis if needed.

## Porcine epidemic diarrhea virus (PEDV) challenge

On day 22 of the trial, the sham challenge (groups 1, 2, 3) and the PEDV challenge (groups 4, 5, 6) were performed by orogastric gavage using an 18 French rubber catheter. Each pig in treatment groups 1, 2, and 3 was inoculated with 10 mL of a PEDV-negative virus culture medium. Each pig in treatment groups 4, 5, and 6 was challenged with 10 mL of PEDV-positive cell culture containing $10^4$ median tissue culture infective doses ($TCID_{50}$) of PEDV per mL. Ten-mL aliquots of PEDV-positive and PEDV-negative inoculum were collected at the time of inoculation and submitted for PEDV PCR to confirm status.

## Biological sample collection

**Pig weights and fecal swabs.** Pig weights were obtained on arrival (day 0), at commencement of study diets (day 3), on day of inoculation (day 22), and on day of necropsy (day 26). At each weigh point, the scale was calibrated with a 20-kg calibration weight. Average daily gain (ADG) was calculated for the 23 days of the study period and reflected the time in which pigs were fed the treatment diets (day 3 to day 26).

Fecal swabs were collected on arrival (day 0), at commencement of feeding study diets (day 3), after 11 days (day 14) and 18 days (day 21) on the study diet, on day of inoculation (day 22), at 2 and 3 days post inoculation (dpi), and on the day of necropsy (day 26). Fecal swabs collected at necropsy (4 dpi) were tested individually for PEDV by quantitative real-time reverse transcription PCR. The remaining swabs were stored at -80°C for further analysis if needed.

**Sample collection at necropsy.** Four days after inoculation, all pigs were euthanized by captive bolt and exsanguination and necropsied. If gross pathology was observed at necropsy, observations were recorded and fresh and fixed tissues of affected organs were collected for diagnostic testing. Each pig's gastrointestinal tract was then removed. Zip ties were placed 1 cm distally from the junction of the stomach and duodenum and 1 cm proximal to the ileocecal junction to standardize removal between pigs. The intestines were separated from body wall attachments and laid out on a necropsy table. The large intestine was then removed.

Milking out the contents of the intestines was possible, but was not performed due to concern about disrupting intestinal mucosa for fixation and histopathologic examination. The entire length of the small intestine was measured and recorded. As the small intestine was susceptible to elongation from manual manipulation, the tension applied to the intestine might have greatly affected the measured length. To mitigate variation, two people were solely responsible for measuring small intestinal length (SIL) and were trained to apply equal tension to facilitate consistency between measurers. The weight of the gastrointestinal tract was recorded on a digital 500-g × 0.01-g scale that was calibrated with a 100-g calibration weight. Small intestine weight-body weight (SIWB) is the weight of the small intestine divided by body weight to create a standardized weight for each pig, which was then used in the statistical models.

The small intestinal tract was folded on itself to create four segments of equal length in a W formation. From the proximal end, the sample sites were duodenum (W1), proximal jejunum (W2), mid-jejunum (W3), distal jejunum (W4), and ileum (W5). Two 1-cm sections were collected at each of the five sites for fresh and fixed tissues.

## Immunohistochemistry

Histopathology slides were prepared for PEDV immunohistochemistry (IHC) for each of the five small intestinal sections of all pigs as described in Madson et al.[1] Viral antigens (PEDV) were detected and semi-quantitatively scored[1] on the basis of the following criteria: 0 = no signal; 1 = 1% to 10% of villous enterocytes within section showing a positive signal; 2 = 11% to 50% of villous enterocytes showing a positive signal; and 3 = 51% or more of villus enterocytes showing a positive signal.[1] All scoring was performed by a veterinary pathologist blinded to treatment allocation.

## Histopathology and atrophic enteritis scoring

A veterinary pathologist, blinded to treatment allocation, measured three perceived full-length villi and crypts per section using a computerized image system (Olympus DP72 camera, cellSens digital imaging software, Olympus, Waltham, Massachusetts). The mean villus length and crypt depth were calculated for each segment and used to determine villus height-to-crypt-depth ratios (VCR).[1] Atrophic enteritis (AE) scoring was performed for each of the five small intestinal sections of each pig. Scores were based on the following criteria: 0 = no enteritis observed; 1 = mild atrophic enteritis; 2 = moderate atrophic enteritis; and 3 = severe atrophic enteritis. Scoring was performed by a single veterinary pathologist blinded to treatment allocation.

## Inoculum preparation

To generate the inoculum, PEDV US prototype strain isolate USA/IA19338/2013 was propagated and virus concentration was determined on Vero cells (ATCC CCL-81).[15] The eighth passage of the virus on cell culture was diluted with post-inoculation medium to a final concentration of $10^4$ $TCID_{50}$ per mL and stored at -80°C upon use.[15]

## Porcine epidemic diarrhea virus PCR and quantitation

A previously described PEDV nucleocapsid (N) gene-based qualitative real-time reverse transcription PCR (qRT-PCR) was used in this study for the detection of PEDV RNA.[1,8,15,16] Polymerase chain reaction amplification was performed using Path-ID Multiplex One-Step RT PCR kit (Thermo Fisher Scientific, Carlsbad, California) on an Applied Biosystem 7500 fast instrument (Thermo Fisher Scientific) and analyzed by system software. Serial 10-fold dilutions of in vitro transcribed RNA standards were used in the PEDV N gene-based qRT-PCR to generate standard curves and quantify viral loads (genome copies per mL) in test samples.[8] Results of PCR testing were reported as cycle threshold (Ct) values, with Ct values ≥ 36 considered negative.

## Cecum and colon dry matter (DM)

Cecum and colon contents were milked out into separate sterile sample containers. These specimens were frozen at -20°C and then submitted for DM analysis. Digital photographs of the colon contents were taken for fecal consistency scoring.

Determination of cecum and colon DM was performed under standard operating protocols and supervision of one of the authors (SG). Cecum and colon contents were thawed over a 24-hour period, and 15 g of each sample was weighed out on a 500-g × 0.01-g scale. A volume of 20 mL of 1:32 accelerated hydrogen peroxide (Accel disinfectant; Virox Technologies Inc, Oakville, Ontario, Canada) was added to each sample. Aluminum pans were used to weigh out two 5.00-g aliquots of cecal contents on a 200-g × 0.01-g scale. This was repeated for colon contents of each pig. All samples were placed in a large convection oven (Yamato Mechanical Convection Oven, model DKN810, Santa Clara, California) at 20.6°C. At 48 hours, samples were removed and placed into a plastic desiccator to cool, and then weighed again on the 200-g × 0.01-g scale. The following equation to determine DM percentage equals

$$\frac{\text{dry weight} - \text{pan weight}}{\text{wet weight} - \text{pan weight}} \times 100$$

The mean DM of the two aliquots for each pig for both cecum and colon was calculated.

## Fecal scoring methods

Photographs of colon contents were taken for each pig and assigned a fecal consistency score by a veterinarian using the photographs and blinded to treatment allocation. Fecal consistency was scored on a scale of 1 to 4, where 1 = normal; 2 = mild diarrhea; 3 = moderate diarrhea; and 4 = severe watery diarrhea.

## Statistical analysis

Responses were analyzed using linear mixed models for each variable of interest. For analyses of intestinal variables, IHC, AE, VCR, PEDV genome copies per mL, treatment group, intestinal segment, and their interactions were used as fixed effects, whereas room and animal were used as random effects. A natural log transformation for the response variable PEDV genome copies per mL was performed to meet normality assumptions for its generalized linear mixed model. For the analyses of the following variables (ADG, cecum dry matter, colon dry matter, small intestine length, small intestine weight per kg body weight, and fecal score), treatment group was the fixed effect and room was the random effect. Comparisons among groups were assessed using F-tests followed by Tukey's *t* tests for multiple comparisons. Differences were considered significant at $P < .05$. All analysis was performed on SAS 9.4 (SAS institute Inc, Cary, North Carolina).

# Results

## Pre-trial contamination screening

Samples collected from all pigs on the day

of arrival were negative by PRRSV pooled PCR and individual PRRSV ELISAs on serum. Porcine epidemic diarrhea virus PCR tests on pooled fecal swabs and PEDV ELISA tests on serum were also all negative. For samples collected on the day of inoculation, pools of fecal swabs from all groups and PEDV-negative cell culture inoculum were PEDV-negative on PCR.

### Clinical assessment

Pigs were generally healthy and active and there was no mortality during the trial. Fecal staining of pen walls or pigs, acute dehydration, vomiting, and lethargy were not observed in any treatment group after inoculation with PEDV.

### Gross pathology

For PEDV-positive groups and at all diet inclusion levels of *B subtilis* C-3102, the small intestines were thin, dilated, and filled with watery ingesta. In the PEDV-negative groups, no gross lesions were noted for the small intestine at necropsy.

## Immunohistochemistry (IHC) score

Results for pairwise comparisons of IHC scores between treatment groups are presented in Table 2 for each intestinal segment. There were significant differences in IHC scores between groups 4 and 5 and 4 and 6 for several segments. There were no significant differences in the IHC scores for any intestinal segments between groups 1 and 2, 1 and 3, 1 and 5, 2 and 3, 2 and 5, 3 and 5, and 5 and 6.

### Villus-to-crypt (VCR) ratio

Table 3 presents comparisons of VCRs between treatment groups for each segment. Villus-to-crypt ratios were significantly higher in groups 1, 2, and 3 (all PEDV-negative) than in Group 4 (PEDV-positive), and were significantly lower in Group 4 than in Group 5.

### Atrophic enteritis (AE)

Table 4 reports significant pairwise comparisons of AE score for each segment between treatment groups. Atrophic enteritis score was significantly higher in group 4 than in groups 5 and 6 for several segments within each comparison.

### Quantitative real-time reverse transcription PCR for porcine epidemic diarrhea virus

The PEDV-positive cell-culture inoculum was PEDV-positive (cycle threshold value = 17.5). For fecal swabs collected on day 4 post inoculation, treatment groups 1, 2, and 3 tested PEDV-negative by PCR. Treatment groups 4, 5, and 6 were PEDV PCR-positive and further quantification was performed on each individual swab. Mean log PEDV genome copies per mL and standard error (in parenthesis) for groups 4, 5, and 6 were 19.18 (3.35), 13.29 (3.35), and 15.66 (3.35). None of the differences in pairwise comparisons between treatment groups were significant at $P < .05$ for mean log genome copies per mL of feces.

**Table 2:** Mean differences* and *P* values† for pairwise comparisons of porcine epidemic diarrhea virus (PEDV) immunohistochemistry (IHC) scores between treatment groups for each of the five intestinal segments assessed (W1 to W5)

| | | W1 | W2 | W3 | W4 | W5 |
|---|---|---|---|---|---|---|
| **Groups** | | **Difference (*P*)** | **Difference (*P*)** | **Difference (*P*)** | **Difference (*P*)** | **Difference (*P*)** |
| 1 | 2 | 0 (1) | 0 (1) | 0 (1) | 0 (1) | 0 (1) |
| 1 | 3 | 0 (1) | 0 (1) | 0 (1) | 0 (1) | 0 (1) |
| 1 | 4 | **-1 (< .001)** | **-2.4 (< .001)** | **-2.3 (< .001)** | **-2.3 (< .001)** | **-2 (< .001)** |
| 1 | 5 | -0.2 (.64) | -0.5 (.24) | -0.5 (.24) | -0.5 (.24) | -0.4 (.35) |
| 1 | 6 | -0.4 (.35) | **-0.9 (.04)** | **-0.9 (.04)** | **-0.9 (.04)** | **-0.9 (.04)** |
| 2 | 3 | 0 (1) | 0 (1) | 0 (1) | 0 (1) | 0 (1) |
| 2 | 4 | **-1 (< .001)** | **-2.4 (< .001)** | **-2.3 (< .001)** | **-2.3 (< .001)** | **-2 (< .001)** |
| 2 | 5 | -0.2 (.64) | -0.5 (.24) | -0.5 (.24) | -0.5 (.24) | -0.4 (.35) |
| 2 | 6 | -0.4 (.35) | **-0.9 (.04)** | **-0.9 (.04)** | **-0.9 (.04)** | **-0.9 (.04)** |
| 3 | 4 | **-1 (< .001)** | **-2.4 (< .001)** | **-2.3 (< .001)** | **-2.3 (< .001)** | **-2 (< .001)** |
| 3 | 5 | -0.2 (.64) | -0.5 (.24) | -0.5 (.24) | -0.5 (.24) | -0.4 (.35) |
| 3 | 6 | -0.4 (.35) | **-0.9 (.04)** | **-0.9 (.04)** | **-0.9 (.04)** | **-0.9 (.04)** |
| 4 | 5 | 0.8 (.06) | **1.9 (< .001)** | **1.8 (< .001)** | **1.8 (< .001)** | **1.6 (.002)** |
| 4 | 6 | 0.6 (.16) | **1.5 (< .001)** | **1.4 (< .01)** | **1.4 (< .01)** | **1.1 (.01)** |
| 5 | 6 | -0.2 (.64) | -0.4 (.35) | -0.4 (.35) | -0.4 (.35) | -0.5 (.24) |

* Treatment groups described in Table 1. Mean IHC scores were compared between treatment groups listed in the first two columns for each of the five intestinal segments assessed (W1 to W5). Intestinal segments examined: duodenum (W1), proximal jejunum (W2), mid-jejunum (W3), distal jejunum (W4), and ileum (W5).

† *P* refers to the *P* value for the difference in mean IHC scores between the two groups listed on each row, generated from Tukey's adjustment for multiple comparisons. Pooled standard error, 0.4. *P* values < .05 (bold print) were considered statistically significant.

**Table 3:** Mean differences* and *P* values† for pairwise comparisons of villus height-to-crypt-depth ratios (VCRs) between treatment groups for each of the five intestinal segments assessed (W1 to W5)

| | | W1 | W2 | W3 | W4 | W5 |
|---|---|---|---|---|---|---|
| **Groups** | | **Difference (*P*)** | **Difference (*P*)** | **Difference (*P*)** | **Difference (*P*)** | **Difference (*P*)** |
| 1 | 2 | -0.011 (.96) | **-0.580 (.01)** | -0.334 (.15) | -0.345 (.13) | -0.146 (.53) |
| 1 | 3 | **0.492 (.03)** | -0.294 (.20) | -0.100 (.66) | -0.112 (.62) | -0.0554 (.81) |
| 1 | 4 | 0.395 (. 09) | **0.715 (.002)** | **0.624 (.01)** | **0.500 (.03)** | 0.358 (.12) |
| 1 | 5 | -0.027 (.91) | 0.261 (.26) | 0.0351 (.88) | -0.0860 (.71) | -0.139 (.54) |
| 1 | 6 | 0.123 (.59) | **0.474 (.04)** | **0.482 (.04)** | 0.322 (.16) | 0.270 (.24) |
| 2 | 3 | **0.503 (.03)** | 0.285 (.21) | 0.235 (.31) | 0.233 (.31) | 0.091 (.69) |
| 2 | 4 | 0.406 (.08) | **1.30 (< .001)** | **0.958 (< .001)** | **0.845 (< .001)** | **0.504 (.03)** |
| 2 | 5 | -0.0161 (.94) | **0.841 (< .001)** | 0.369 (.11) | 0.259 (.26) | 0.0066 (.98) |
| 2 | 6 | 0.134 (.56) | **1.05 (< .001)** | **0.816 (.001)** | **0.667 (< .01)** | 0.416 (.07) |
| 3 | 4 | -0.0974 (.67) | **1.01 (< .001)** | **0.723 (< .01)** | **0.612 (.01)** | 0.414 (.07) |
| 3 | 5 | **-0.519 (.02)** | **0.555 (.02)** | 0.135 (.56) | 0.0263 (.91) | -0.084 (.71) |
| 3 | 6 | -0.370 (.11) | **0.768 (< .001)** | **0.581 (.01)** | 0.434 (.06) | 0.325 (.16) |
| 4 | 5 | -0.422 (.07) | **-0.454 (.04)** | **-0.588 (.01)** | **-0.586 (.01)** | **-0.498 (.03)** |
| 4 | 6 | -.272 (.23) | -0.242 (.29) | -0.142 (.54) | -0.178 (.44) | -0.0883 (.70) |
| 5 | 6 | 0.150 (.51) | 0.213 (.35) | 0.446 (.05) | 0.408 (.08) | 0.409 (.08) |

* Treatment groups are described in Table 1. Mean VCRs were compared between treatment groups listed in the first two columns for each of the five intestinal segments assessed. Intestinal segments examined: duodenum (W1), proximal jejunum (W2), mid-jejunum (W3), distal jejunum (W4), and ileum (W5).

† *P* refers to the *P* value for the difference in mean VCRs between the two groups listed on each row, generated from Tukey's adjustment for multiple comparisons. Pooled standard error, 0.229. *P* values < .05 (bold print) were considered statistically significant.

### Macroparameters of gut health

**Cecum and colon dry matter.** Mean cecum and colon DM percentages were determined and pairwise comparisons of DM percentages for both cecum and colon samples revealed several statistically significant differences reported in Table 5.

**Fecal score.** Mean fecal score was recorded; however, there were no significant differences in fecal consistency for all pairwise comparisons of the six treatment groups ($P \geq .05$).

**Small intestine weight by body weight (SIWB) and SIL.** There were no significant differences in least squares mean SIWB or SIL between pairwise comparisons of all groups.

**Average daily gain.** Pairwise comparisons between treatment groups for 23-day ADG using Tukey's least squares means adjustment for multiple comparisons were not significantly different for any of the treatment groups.

## Discussion

The literature available on the effects of DFMs on enteric disease or on reducing shedding of pathogens is limited. Trials assessing the effect of *Lactobacillus* species on fecal shedding of enteric pathogens and ADG in *Salmonella* Typhimurium and rotavirus challenge models have shown limited positive effects on study outcomes.[5,6] There is also currently a patent (WO 2005007834 A1) submitted for a *Lactobacillus* species with the claim that this strain can inhibit growth of enteric coronavirus in vitro. Sow fecal shedding, piglet mortality, and piglet diarrhea were assessed in sows and gilts fed *B subtilis* C-3102 for 3 weeks at $10^7$ CFUs per gram of feed.[17] Sows receiving *B subtilis* C-3102 experienced a reduction in *Clostridium perfringens* fecal shedding and an increase in lactobacilli fecal shedding after 21 days of continuous exposure to the diet. *Bacillus subtilis* C-3102 is also reported to have a positive effect on sow feed consumption, wean-to-estrus interval, piglet birth weight, and fecal shedding of *Escherichia coli* and *Clostridium* species.[18] Upon review of the literature, comparable studies examining associations between *B subtilis* C-3102 and intestinal histopathology and macroparameters of gut health following PEDV infection were not found.

Significant differences in IHC score between Group 1 and Group 4 on control diets indicated that the PEDV challenge did cause enteric infection with PEDV in the study pigs. Mean IHC scores for Group 4 at 4 dpi were comparable to those reported for 3-week-old pigs.[1] For PED-positive groups, those fed *B subtilis* C-3102 (groups 5 and 6) had lower IHC scores than those fed control diets (Group 4), indicating that there was a lower percentage of enterocytes infected with PEDV in groups 5 and 6. The mechanism for this difference in IHC scores is unknown and pigs were not followed beyond 4 dpi to evaluate the duration and magnitude of this difference over a longer time period. There was no statistical difference in IHC scores between Group 5 and Group 6, although both were significantly lower than in Group 4. This suggests that the effect on IHC may not be dependent on dietary

**Table 4:** Mean differences* and *P* values† for pairwise comparisons of atrophic enteritis (AE) scores between treatment groups for each of the five intestinal segments assessed

| Groups | | W1 | W2 | W3 | W4 | W5 |
|---|---|---|---|---|---|---|
| | | Difference (*P*) | Difference (*P*) | Difference (*P*) | Difference (*P*) | Difference (*P*) |
| 1 | 2 | 0 (1) | 0 (1) | 0 (1) | 0 (1) | 0 (1) |
| 1 | 3 | -0.5 (.16) | 0 (1) | -0.1 (.78) | 0 (1) | 0 (1) |
| 1 | 4 | **-1.2 (< .001)** | **-2 (< .001)** | **-1.6 (< .001)** | **-1.6 (< .001)** | **-1.4 (< .001)** |
| 1 | 5 | -0.4 (.26) | -0.4 (.26) | -0.2 (.57) | -0.1 (.78) | -0.2 (.57) |
| 1 | 6 | **-0.7 (.049)** | **-1.1 (< .01)** | **-0.8 (.02)** | **-0.9 (.01)** | **-0.9 (.01)** |
| 2 | 3 | -0.5 (.16) | 0 (1) | -0.1 (.78) | 0 (1) | 0 (1) |
| 2 | 4 | **-1.2 (< .001)** | **-2 (< .001)** | **-1.6 (< .001)** | **-1.6 (< .001)** | **-1.4 (< .001)** |
| 2 | 5 | -0.4 (.26) | -0.4 (.26) | -0.2 (.57) | -0.1 (.78) | -0.2 (.57) |
| 2 | 6 | **-0.7 (.049)** | **-1.1 (.002)** | **-0.8 (.02)** | **-0.9 (.01)** | **-0.9 (.01)** |
| 3 | 4 | **-0.7 (.049)** | **-2 (< .001)** | **-1.5 (< .001)** | **-1.6 (< .001)** | **-1.4 (< .001)** |
| 3 | 5 | 0.1 (.78) | -0.4 (.26) | -0.1 (.78) | -0.1 (.78) | -0.2 (.57) |
| 3 | 6 | -0.2 (.57) | **-1.1 (.002)** | **-0.7 (.049)** | **-0.9 (.01)** | **-0.9 (.01)** |
| 4 | 5 | **0.8 (.03)** | **1.6 (< .001)** | **1.4 (< .001)** | **1.5 (< .001)** | **1.2 (< .001)** |
| 4 | 6 | 0.5 (.16) | **1.6 (< .001)** | **0.8 (.03)** | 0.7 (.49) | 0.5 (.16) |
| 5 | 6 | -0.3 (.40) | **-0.7 (.049)** | -0.6 (.09) | **-0.8 (.02)** | **-0.7 (.049)** |

* Treatment groups are described in Table 1. Mean AE scores were compared between treatment groups listed in the first two columns for each of the five intestinal segments assessed. Sample sites were duodenum (W1), proximal jejunum (W2), mid jejunum (W3), distal jejunum (W4), and ileum (W5).

† *P* refers to the *P* value for the difference in mean AE scores between the two groups listed on each row, generated from Tukey's adjustment for multiple comparisons. Pooled standard error was 0.4. *P* values < .05 (bold print) were considered statistically significant.

concentration of *B subtilis* C-3102. The sample size of this study was small and the study had insufficient power to elucidate and quantify a dose-dependent relationship between Group 4 and Group 5 compared to Group 4 and Group 6. This represents an area for future studies to investigate further.

The findings described in the comparisons between treatment groups for IHC scores were also identified in the atrophic enteritis scores. As atrophic enteritis is a pathologic lesion association with enteric viral pathogens, and IHC is a quantitative measure of PEDV infection of the enterocytes, it is logical that these scores would mirror each other. In treatment Group 3, there was mild atrophic enteritis in the W1 and W3 segments. As these segments were IHC-negative for PEDV, and the fecal swabs from these pigs were PEDV-negative on PCR, this mild enteritis could be attributed to other enteric viruses such as rotavirus, or to enteric inflammation related to diet or to other bacterial pathogens.

In swine, *B subtilis* increases the prevalence of bacterial colonization with *Streptococcus* species, *Bifidobacterium* species, and *Lactobacillus* species, which may act to competitively exclude pathogens from colonizing the mucosal surface.[3,10,19] Lactobacilli produce lactic acid, which lowers gut pH and optimizes the gut environment for commensal bacteria.[3,6] *Bacillus* species also produce catalases and proteases that may serve as exogenous digestive enzymes. These enzymes can alter the protein content of gut ingesta and create optimal conditions for *Lactobacillus* colonization and growth.[20] The resultant decrease in intestinal pH and increase of commensal bacteria may impact the ability of PEDV to infect enterocytes and may explain the lower IHC scores in Group 4 than in Group 5 or Group 6.

Values for VCR for each intestinal region were uniformly smaller, across all six treatment groups, than those reported for 3-week-old pigs.[1,21] Pigs in this study were approximately 5 weeks old at the time of necropsy. Villus-crypt ratio is dependent on age, diet, and genetic factors,[1] thus the lower VCR observed here for all treatment groups (1, 2, 3, 4, 5, and 6) may reflect a difference in pig age between the studies.

There was a significantly lower VCR for PEDV-challenged pigs in Group 4 compared to those that were sham challenged (groups 1, 2, and 3). Villus length and crypt depth are highly dynamic and reflect local insult and subsequent regeneration. The VCR provides a snapshot of current status of the villi and crypts at the time of necropsy, and the VCR is expected to increase post inoculation as the pig recovers.[1,7] Although VCRs were significantly higher in PEDV-positive pigs fed *B subtilis* C-3102 than in controls, the clinical significance of this finding in terms of ADG and morbidity is unclear. It would be necessary to stagger necropsies over several dpi and extend the duration of the study to assess the long-term effect of *B subtilis* C-3102 on VCR after PEDV challenge.

In this study, quantitation of the PEDV challenge was used to verify that the challenge dose was homologous between groups. Groups 4, 5, and 6 were all PEDV-positive at 4 dpi and there were no significant differences in genome copies per mL shed in the feces. This indicates that continuously feeding pigs

**Table 5:** Pairwise comparison of mean cecum and colon DM percent between treatment groups*

| Groups | | Difference in mean cecum DM (%) | *P* value for cecum DM comparison between groups† | Difference in mean colon DM (%) | *P* value for colon DM comparison between groups† |
|---|---|---|---|---|---|
| 1 | 2 | 0.28 | 1.00 | 1.25 | .74 |
| 1 | 3 | -0.23 | 1.00 | 0.83 | .93 |
| 1 | 4 | 3.37 | **.01** | 2.71 | .15 |
| 1 | 5 | 1.77 | .16 | 5.89 | **< .01** |
| 1 | 6 | 1.61 | .22 | 1.55 | .57 |
| 2 | 3 | -0.51 | .95 | -0.42 | 1.00 |
| 2 | 4 | 3.09 | **.02** | 1.46 | .62 |
| 2 | 5 | 1.49 | .27 | 4.65 | **.02** |
| 2 | 6 | 1.33 | .36 | 0.30 | 1.00 |
| 3 | 4 | 3.60 | **< .01** | 1.88 | .40 |
| 3 | 5 | 2.00 | .11 | 5.06 | **.01** |
| 3 | 6 | 1.84 | .14 | 0.72 | .96 |
| 4 | 5 | -1.60 | .22 | 3.19 | .08 |
| 4 | 6 | -1.76 | .16 | -1.16 | .79 |
| 5 | 6 | -0.16 | 1.00 | -4.35 | **.02** |

* Treatment groups are described in Table 1. Mean differences in colon and cecum percent DM calculated by subtracting the mean cecal or colon dry matter percentage in column two from the percentage in column one.

† *P* values were generated from Tukey's adjustment for multiple comparisons. Pooled standard error of cecum DM content was 0.61% and of colon DM was 0.91%. *P* values < .05 (bold print) were considered statistically significant.

DM = dry matter.

with *B subtilis* C-3102 after PEDV challenge did not alter fecal virus shedding. Groups 1, 2, and 3 remained PEDV-negative throughout the trial, thus the PEDV-positive and PEDV-negative cell culture inoculum was successfully administered without cross-contamination at or after inoculation.

The 23-day ADG was lower than industry standards of 250 to 350 g per day for nursery pigs for the first 3 weeks post weaning.[22] Conventionally, pigs are weaned at 21 days, but pigs were weaned at 14 days of age for this study. Clinical signs of PEDV (diarrhea, dehydration, mortality, and depression) are age dependent.[1,2] As the goal of the study was to produce a successful PEDV infection with enteric lesions, 14-day-old pigs, in lieu of 21-day-old pigs, were utilized in this study. Technical representatives for Calpis Co Ltd and Quality Technology International recommended feeding *B subtilis* C-3102 continuously for approximately 3 weeks prior to PEDV challenge to provide optimal opportunity for the product to impact the gut. This extended feeding period could negatively impact clinical severity of PEDV challenge by increasing pig age at challenge, thus it was elected to start the trial with a younger pig, at the age of 14 days.

There were no differences in SIWB or SIL between the groups. Small intestinal weight-body weight was impacted by the volume and composition of intestinal ingesta. Despite the large potential for variability, the mean SIWB did not differ between groups, and there was also no difference between groups for SIL. The SILs determined in this study are comparable to SILs in 35- and 39-day-old pigs.[23,24] The functional significance of SIL is related to digestion capacity to maximize growth and is strongly related to pig age and growth rate.[24] As ADG increases with days on feed in the growing period,[24] a difference in SIL between groups might have been appreciated if the duration of the study had been extended.

Fecal scores for all groups did reflect mild looseness in the stool; however, there was no difference in fecal scores between groups. This finding indicates that PEDV status is not correlated with visual fecal scores in weaned pigs under the conditions of this study. As PEDV status is critical to personnel, equipment, trucking logistics, and biosecurity, the results of the fecal score analysis highlight the importance of conducting diagnostic testing to ascertain the PEDV status of weaned pigs.

The cecum and colon DM were measured to provide an objective assessment for fecal consistency. Keeping PEDV status constant, cecum DM did not differ significantly between diet groups. Disease status did impact cecum DM, but not colon DM in this study, as Group 1 and Group 4 did not differ significantly in colon DM. For future PEDV studies, cecum DM appears to have more utility than colon DM in reflecting disease-associated changes in fecal consistency.

The findings of this study support an association between feeding *B subtilis* C-3102 and mitigating severity of PEDV lesions, including lower IHC scores, lower AE scores, and higher VCRs at 4 dpi in nursery pigs challenged with PEDV, compared to cohorts that did not receive *B subtilis* C-3102. However, amount of virus shedding at 4 dpi did not differ with *B subtilis* C-3102 feeding. The results did appear to show that Group 5 animals benefited more than Group 6 animals

from treatment with *B subtilis* C-3102. The study was not designed to measure dose-dependent effects of *B subtilis* C-3102, and an additional study with this purpose would be needed to ascertain if differences between Group 5 and Group 6 were truly due to a dose-dependent or random effect. The impact of these parameters on morbidity, mortality, amount and duration of virus shedding, ADG, and feed efficiency during the entire growing period is unknown and should be assessed with an additional study of longer duration and larger sample size. In a field scenario, it would be rare for DFM administration to precede an enteric disease outbreak by at least 2 weeks. If exposure to *B subtilis* C-3102 before PEDV exposure is critical to impact enteric lesions, then application in a field scenario may be challenging, as it would require administration to all groups or the identification of "at risk" groups for pre-emptive feeding.

## Implications

- Under the conditions of this study, there is no grossly detectable difference in fecal consistency between PEDV-positive and PEDV-negative pigs fed the direct-fed microbial *B subtilis* C-3102.
- Pigs that receive *B subtilis* C-3102 prior to PEDV challenge have lower PEDV IHC scores and better histopathology scores and villus-to-crypt ratios after PEDV challenge, compared to control cohorts.


### Acknowledgments

Thank you to the Swine Medicine Education Center summer interns and LAR animal care takers for their significant contributions to the live-animal work and sample collection.

### Conflict of interest

Calpis America, Inc, and QTI, Inc, provided funding for the animals and housing.


### Disclaimer

Scientific manuscripts published in the *Journal of Swine Health and Production* are peer reviewed. However, information on medications, feed, and management techniques may be specific to the research or commercial situation presented in the manuscript. It is the responsibility of the reader to use information responsibly and in accordance with the rules and regulations governing research or the practice of veterinary medicine in their country or region.

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# Checkoff launches new version of TQA

The National Pork Board (NPB) launched the latest version of the Transport Quality Assurance (TQA) program in March. Version 6 includes updated content in the handbook and contextual interactions in the online training. This new version allows handlers seeking first-time certification to complete the program. However, they must be granted access to the online certification from their TQA advisor. Handlers can locate a TQA advisor under the Certifications tab on **www.pork.org**.

All current TQA advisor certifications expire on May 31, 2017. The NPB requires that advisors do every other advisor certification face-to-face. Advisors who can recertify using the online program should have received an e-mail from the National Pork Board with access to the online materials. If not, they can request a new e-mail by contacting the NPB Service Center (800-456-7675). Advisors who are required to recertify at a face-to-face training can register for available trainings under the Certifications tab of **www.pork.org**.

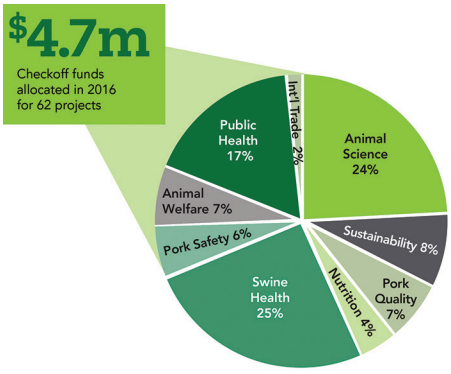
# Checkoff's science and technology team delivers results

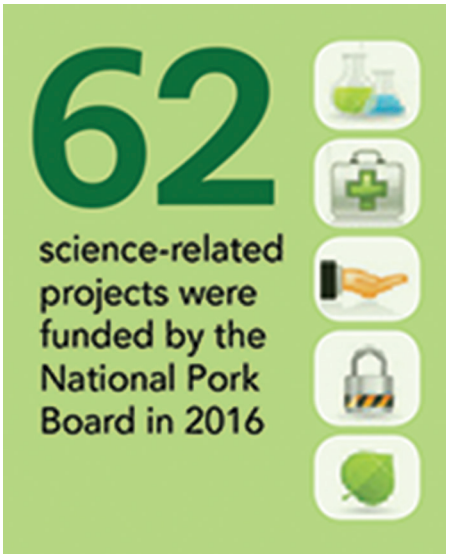
The Pork Checkoff's producer-led science and technology department committees continue to create value by focusing on research projects that help address pork industry issues. This held true in 2016 in several key areas, including substantial progress on the National Pork Board's goal of reducing the impact of porcine reproductive and respiratory syndrome and in allocating record funds for antibiotic-related research and solutions.

"Pork production is a science-based business, and producers deserve to get the maximum return on their investment," said Dave Pyburn, senior vice president of science and technology for the Checkoff.

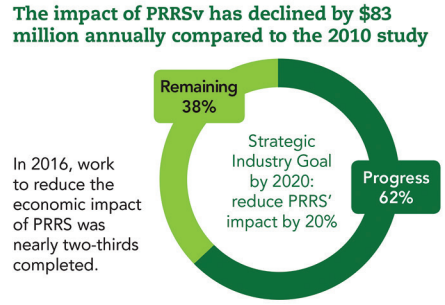
He added, "Thanks to innovative collaboration and lots of hard work and strategic leadership, the Pork Checkoff continues to deliver positive results for people, pigs, and the planet through funded research."

For more information, contact Dave Pyburn at **DPyburn@pork.org** or 515-223-2634.



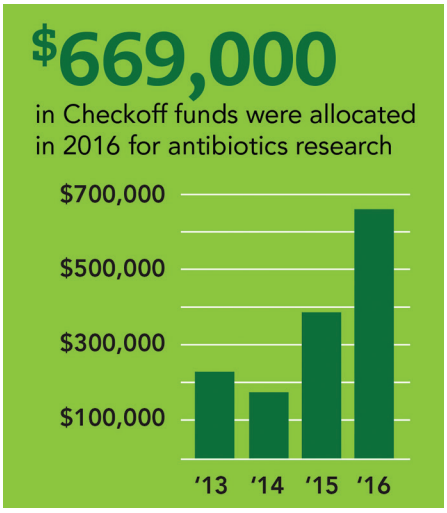








*Source: Veterinary Diagnostic and Production Animal Medicine, ISU College of Veterinary Medicine.*

*Note:* Adjusted for changes in prices and the size of the national herd since 2010.




*NPB news continued on page 141*

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*NPB news continued from page 139*

# Checkoff partners with *National Hog Farmer* to produce antibiotic Webinar

The Pork Checkoff hosted a 1-hour Webinar, "How to Succeed with the New Antibiotic Regulations," on February 21, that was heard and seen in more than 20 countries. The panel of experts included Dr Dave Pyburn, vice president of science and technology for the National Pork Board, Dr Liz Wagstrom, chief veterinarian for the National Pork Producers Council, and Dr Harry Snelson, director of communications for the American Association of Swine Veterinarians. All three gave updates on how the new FDA antibiotic rules are affecting US producers and answered participant questions. If you missed the live event, the on-demand version is now available at **www.pork.org/antibiotics**.

For more information, contact Mike King at **MKing@pork.org** or 515-223-3532.

# Checkoff's Pork Store offers valuable resources

Although some veterinarians may not realize it, most science- and consumer-oriented resources are available to them and their clients at no cost through the National Pork Board's Pork Store. With its easier-than-ever search and ordering system, users can easily navigate through the available materials and get instant items such as PDF-based fact sheets, or order hard copies of items such as PQA Plus materials, foreign animal disease resources, sustainability items, and much more. The Pork Store is easily accessed via **www.pork.org** and clicking on the large square labeled "the Pork Store."

For more information, contact Mike King at **MKing@pork.org** or 515-223-3532.

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***DIRECTIONS FOR USE**
Feed at 73 grams avilamycin per ton of Type C medicated feed (80 ppm) as the sole ration for 21 consecutive days. The veterinarian may direct feeding for up to a total of 42 consecutive days, based on clinical assessment. Feed to pigs that are at risk of developing, but net yet showing, clinical signs of diarrhea in the presence of pathogenic *Escherichia coli*.

**IMPORTANT SAFETY INFORMATION**
**CAUTION:** Federal law restricts medicated feed containing this veterinary feed directive drug (VFD) to use by or on the order of a licensed veterinarian.

- No withdrawal period required when fed according to the label.
- To assure responsible antimicrobial drug use in pigs, do not administer to pigs 14 weeks of age or older or for more than a lifetime total of 42 days.
- Avoid inhalation, oral exposure, and direct contact with skin or eyes.
- VFD expiration date must not exceed 90 days from the date of issuance. VFDs for avilamycin shall not be refilled.
- Avilamycin has not been demonstrated to be effective in pigs showing clinical signs of diarrhea prior to the start of medication.

[1]Elanco Animal Health. Data on file.


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# AASV NEWS

## AASV installs 2017 officers

Dr Alex Ramirez was installed as the president of the American Association of Swine Veterinarians on February 28, 2017, during the association's 48th annual meeting in Denver, Colorado. He succeeds Dr George Charbonneau, who is now immediate past president. Dr Scanlon Daniels has ascended to president-elect. The newly elected vice president is Dr Nathan Winkelman.

AASV officers (left to right) Dr Nathan Winkelman, Dr Scanlon Daniels, Dr George Charbonneau, and Dr Alex Ramirez

**AASV President Dr Alejandro "Alex" Ramirez** (ISU '93) grew up in Guadalajara, Mexico. He obtained his Doctor of Veterinary Medicine degree from the Iowa State University (ISU) College of Veterinary Medicine and joined Valley Veterinary Center, a mixed-animal practice, in Cherokee, Iowa. In 2004, Alex left practice and returned to ISU to pursue a teaching career. He obtained a Master of Public Health degree from the University of Iowa and concluded a PhD at ISU in 2011.

Dr Ramirez joined AASV in 2002. He first served as a substitute judge for the student presentations at the AASV Annual Meeting. Shortly thereafter, he was asked to co-chair the student oral competitions. He has also co-chaired the Collegiate Activities Committee for the past few years and has served on the *Journal of Swine Health and Production* Editorial Board since 2010. He represented District 6 on the AASV Board of Directors from 2013 to 2015.

When asked to comment on his thoughts about the future of AASV and his tenure as president, Dr Ramirez said, "I am excited about this honor and opportunity to lead AASV as our great association and its members continue to focus on helping advance the health and wellbeing of the pigs we care for. We need to continue protecting public health through securing a wholesome and safe protein source to feed the world."

**AASV President-elect Dr C. Scanlon Daniels** (ISU '98) grew up on a family owned and operated livestock enterprise in central Iowa. He attended Iowa State University where he received a BS degree in Animal Science and a DVM degree. He also has an MBA from the University of Guelph. Dr Daniels has been previously employed as a staff veterinarian by Iowa Select Farms and Seaboard Foods. Currently, he and his wife, Dr Angela Daniels, operate a diversified food-animal veterinary practice, laboratory, and multi-species contract research organization in Dalhart, Texas. Dr Daniels has been active in multiple AASV committees and has served on the AASV Board of Directors representing District 7 on two occasions.

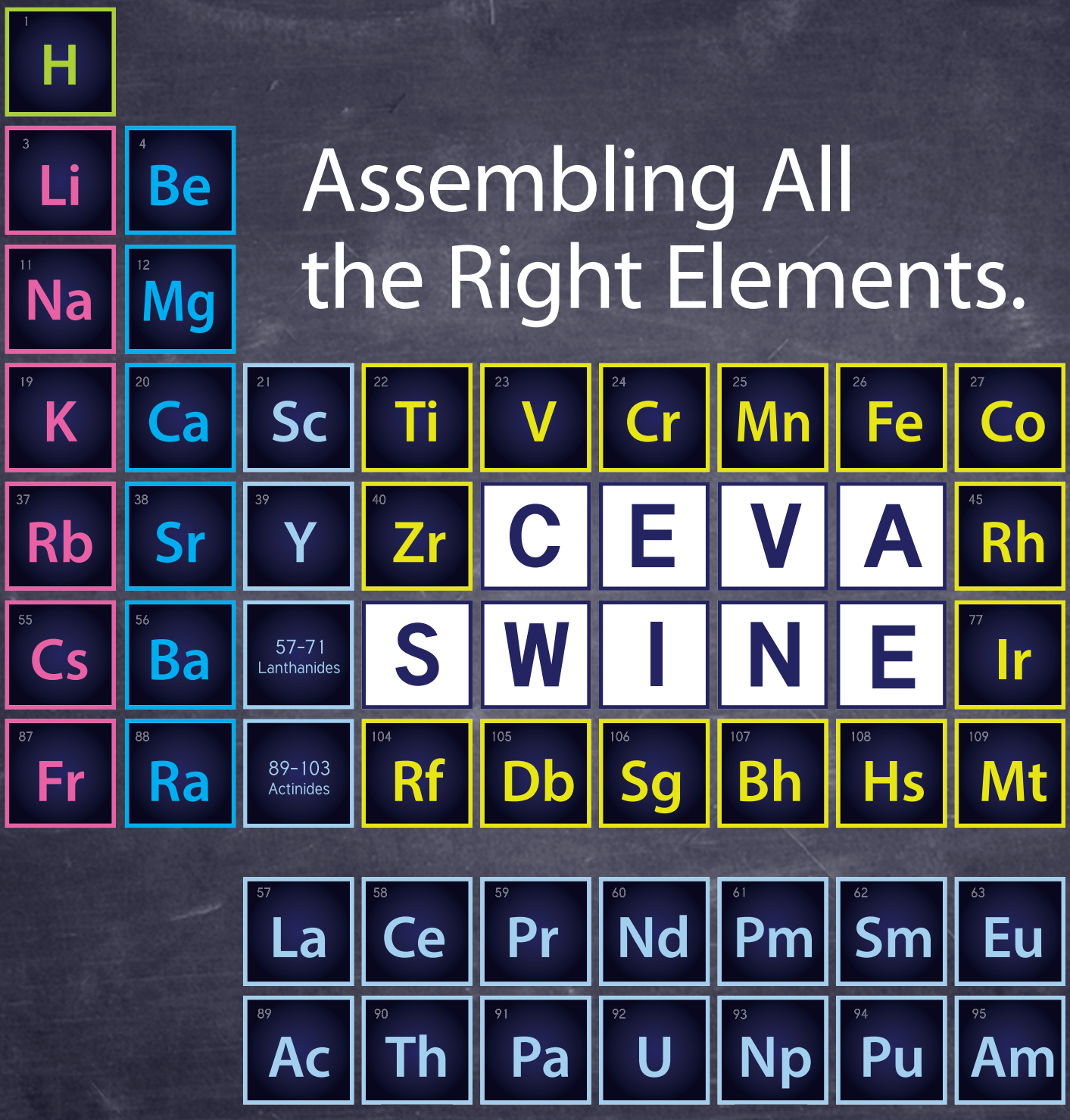
**AASV Vice President Dr Nathan Winkelman** (UMN '84) was raised on a diversified crop and livestock farm near St James, Minnesota. The family farm included a farrow-to-finish swine operation, beef cow-calf herd, feedlots, laying hens, and fieldwork. Dr Winkelman credits his veterinarian uncle, FFA instructor, and local veterinarians for his desire to become a veterinarian.

Dr Winkelman received a BS degree in Animal Science and a DVM from the University of Minnesota. Upon graduation, he joined a swine-exclusive veterinary practice in Morris, Minnesota, with Drs Rod Johnson and Tony Scheiber. Currently, Dr Winkelman is a partner with Dr Adam Mueller in Swine Services Unlimited, Inc, a swine research and consulting practice in Rice, Minnesota. Their business focus is consulting with loyal, progressive pork-producer clients, some of whom they've seen each month for over 35 years! Swine Services Unlimited, Inc, is also a contract research organization conducting swine disease trials, with a special emphasis on *Lawsonia intracellularis* challenge studies.

Dr Winkelman and his wife Deb Bryant (also a veterinarian) raised two children and enjoy a "hobby-farm menagerie" with horses, goats, chickens, dogs, and cats (no pigs, of course) in Sartell, Minnesota. Dr Winkelman has served on the AASV Board of Directors and currently sits on the AASV Foundation Board where he chairs the foundation's Research Project Selection Committee. In addition, Dr Winkelman is an active participant in the AASV-National Pork Board Operation Main Street project, giving presentations to various groups to raise awareness about modern pork production.

Asked to comment on what his election meant to him, Dr Winkelman responded, "I sincerely look forward to the opportunity and challenge to serve the AASV in this capacity. The AASV organization and all my friends and colleagues have been an integral part of a successful career in swine medicine.

*AASV news continued on page 145*

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*AASV news continued from page 143*

Thank you all." He also expressed his appreciation to Dr Brian Schantz for his willingness to also run for office. "He was the first to congratulate me, wish me well, and advised me against incessant late night tweets during my time in office," noted Dr Winkelman.

**AASV Past President Dr George Charbonneau** (OVC '81) grew up in Arnprior, Ontario. He obtained his Doctor of Veterinary Medicine from the Ontario Veterinary College and established a veterinary practice serving southwestern Ontario. George is currently a veterinarian at South West Ontario Veterinary Services and is based in White Lake, Ontario. Dr Charbonneau has served as the president of the Canadian Association of Swine Veterinarians and the Ontario Association of Swine Veterinarians. He was involved in the formation of, and served as the initial chairman of, the Ontario Pork Industry Council. He also represented Canadian swine veterinarians as a district representative on the board of directors of the American Association of Swine Veterinarians. He was the 2012 recipient of the AASV Swine Practitioner of the Year award.

# What's a swine vet worth?

Isn't that what we all want to know? Are your salary and benefits comparable to those of your colleagues? Are you paying your associate veterinarians enough to keep them from searching for greener pastures? What do you need to offer a young veterinarian to be competitive with other offers he or she is likely to receive? The answers to these questions start with YOUR participation in the **2017 AASV Salary Survey!**

If you're an "Active" AASV Member (non-retired veterinarian) in the United States or Canada, go to **www.aasv.org/members/** (username and password required) to obtain a security code and access the online survey. It's much simpler and less painful than the income tax returns you just filed!

Members of AASV are divided into two survey groups, depending on their employment type. The ***practitioner*** survey should be completed by those who oversee pig health for a production or genetics company, as well as those engaged in private practice. Members who work for a university, corporation, or government, that are engaged in education, research, technical services, public health, or regulatory work should complete the survey for ***public/corporate*** veterinarians.

Once the data collection period has ended, the survey results will be pooled and shared with the AASV membership – and we'll have the answers to our questions. Responses are confidential and the results are reported in a manner to assure participant anonymity. The more participation, the more valid the results – so do your part and complete the survey today!

# Call for papers – AASV 2018 Student Seminar

## Veterinary Student Scholarships

The American Association of Swine Veterinarians announces an opportunity for veterinary students to make a scientific presentation during the Student Seminar at the AASV Annual Meeting in San Diego, California, on Sunday, March 4, 2018. Interested students are invited to submit a one-page abstract of a research paper, clinical case study, or literature review for consideration. The submitting student must be a current (2017-2018) student member of the AASV at the time of submission, and must not have graduated from veterinary school prior to March 4, 2018. Submissions are limited to one (1) abstract per student.

Abstracts and supplementary materials must be ***received*** by Dr Maria Pieters (**pieters@aasv.org**) by **11:59 pm Central Daylight Time** on **Wednesday, September 20, 2017** (firm deadline). All material must be submitted electronically. Late abstracts will not be considered. Students will receive an e-mail confirming the receipt of their submission. If they do not receive this confirmation e-mail, they must contact Dr Maria Pieters (**pieters@aasv.org**) by Friday, September 22, 2017, with supporting evidence that the submission was made in time; otherwise, the submission will not be considered for judging. The abstracts will be reviewed by an unbiased, professional panel consisting of private practitioners, academicians, and industry veterinarians. Fifteen abstracts will be selected for oral presentation in the Student Seminar at the AASV Annual Meeting. Students will be notified by October 13, 2017, and those selected to participate will be expected to provide the complete paper or abstract, reformatted for publication, by November 15, 2017.

As sponsor of the Student Seminar, Zoetis provides a total of $20,000 in support to fund travel stipends and the top student presenter scholarship. The student presenter of each paper selected for oral presentation receives a $750 stipend to help defray the costs of attending the AASV meeting.

Veterinary students whose papers are selected for oral presentation compete for one of several veterinary student scholarships awarded through the AASV Foundation. The oral presentations will be judged to determine the amount of the scholarship awarded. Zoetis funds the $5000 scholarship for the student whose paper, oral presentation, and supporting information are judged best overall. Elanco Animal Health provides $20,000 in additional funding, enabling the AASV Foundation to award $2500 each for 2nd through 5th place, $1500 each for 6th through 10th place, and $500 each for 11th through 15th place.

Abstracts that are not selected for oral presentation in the Student Seminar will be considered for participation in a poster session at the annual meeting. Zoetis and the AASV fund a stipend of $250 for each student who is selected and participates in the poster presentation. In addition, the presenters of the top 15 poster abstracts compete for awards ranging from $200 to $500 in the Veterinary Student Poster Competition, sponsored by Newport Laboratories.

Complete information for preparing and submitting abstracts is available on the AASV Web site at **www.aasv.org/annmtg/2018/studentseminar.htm**. Please note: the rules for submission should be followed carefully. For more information, contact the AASV office (Tel: 515-465-5255; Fax: 515-465-3832; E-mail: **aasv@aasv.org**).

# Annual Meeting Report

# AASV Annual Meeting sets records again

The American Association of Swine Veterinarians (AASV) held its 48th annual meeting in Denver, Colorado, February 25-28, 2017. The meeting, held at the Hyatt Regency Denver, drew record attendance of 1200 total attendees, including 724 paid registrants (also a record) and 146 veterinary students from 24 colleges of veterinary medicine. The conference participants hailed from 30 countries, with 245 (20% of the total) from outside the United States. The total attendance also included a record 270 exhibit representatives from 91 companies and organizations (another all-time high).

The meeting participants enjoyed the opportunity to attend numerous educational sessions, including 11 pre-conference seminars, two general sessions, three break-out sessions, research topics, three industrial partners sessions, the Student Seminar, and a poster session featuring 58 posters. In addition, 13 AASV committees met during the annual meeting.

Dr Jeff Zimmerman opened the Monday general session with the Howard Dunne Memorial Lecture. His presentation, entitled "Swine medicine in the 21st century: Immovable Object meets Unstoppable force" explored the conundrum facing swine veterinarians today – our highly efficient system of pork production (The Immovable Object) is jeopardized by our inability to deal with infectious disease (The Unstoppable Force), which is largely the result of the design of our highly efficient production system. One of the key take-aways from Dr Zimmerman's talk is that swine veterinarians need to find ways to make the swine industry more agile and devise solutions that neutralize the power of infectious disease.

Dr Matthew Turner presented the Alex Hogg Memorial Lecture entitled "One Health: roles, responsibilities, and opportunities for swine veterinarians." His presentation explored the history of the One Health movement and the opportunities for swine veterinarians, including food safety, animal welfare, antibiotic resistance, and client and consumer education.

The Monday afternoon concurrent sessions allowed attendees the opportunity to delve deeper into the broad topics of swine diseases, antibiotic use, and managing the reproductive herd for high health and productivity. The Tuesday general session addressed the issues associated with disease control and elimination.

The AASV Awards Reception was held Monday night, followed by the AASV Foundation's annual fund-raising auction. Dr John Waddell presented the Heritage Award to Dr K. T. Wright. This is only the third time the Heritage Award has been presented. Dr Matt Anderson, 2013 AASV president and chair of the 2017 Awards Selection Committee, presented the recipients of the Swine Practitioner of the Year Award (Dr Mike Eisenmenger), the Howard Dunne Memorial Award (Dr Rodger Main), the Meritorious Service Award (Dr Jeff Harker), the Young Swine Veterinarian of the Year Award (Dr Josh Ellingson), and the Technical Services/Allied Industry Veterinarian of the Year Award (Dr Tom Wetzell).

## Swine Practitioner of the Year

**Dr Mike Eisenmenger** was named 2017 **Swine Practitioner of the Year**. The award is given to the swine practitioner who has demonstrated an unusual degree of proficiency and effectiveness in the delivery of veterinary service to clients.

Dr Eisenmenger was born and raised on a small family farm in Cherokee, Iowa. His family farmed and raised hogs, leading to his early interest in swine. He went on to attend Iowa State University where he obtained an undergraduate degree in Animal Science. Dr Eisenmenger earned his DVM in 1983 from the Iowa State University College of Veterinary Medicine.

Upon graduation, Dr Eisenmenger worked for the Cottonwood Veterinary Clinic in Windom, Minnesota, for 13 years. In 1997, he took a job at the Swine Vet Center in Saint Peter, Minnesota, working as a swine consultant for swine producers along with 11 other veterinarians. He has worked for the Swine Vet Center for 21 years.

Dr Eisenmenger served on the 1998 American Association of Swine Practitioners Annual Meeting Planning Committee. He is a member of the American Veterinary Medical Association and the Minnesota Veterinary Medical Association.


Dr Mike Eisenmenger, recipient of the AASV Swine Practioner of the Year Award

Asked to comment about receiving this award, Dr Eisenmenger replied, "It is such an honour being recognized by your peers working in the swine industry. I really want to thank all the mentors I have had working with me through the years. When I joined the Swine Vet Center in 1997, I still recall what Dr Tim Loula told me. "Always do what is right for the client. If you make them healthy, profitable, and the best they can be, it will always be good for you too." The clients I work for have been a big part of this recognition. I also want to thank my parents for teaching me the value of hard work and treating people with respect."

Dr Eisenmenger and his wife reside in Windom, Minnesota. They have four children: Nate (30), Sioux Falls, South Dakota; Matt (28), St Cloud, Minnesota; Nick (25), Bismarck, North Dakota; and Adam (23), Rochester, Minnesota.

## Howard Dunne Memorial Award

**Dr Rodger Main** received the **Howard Dunne Memorial Award**. The award recognizes an AASV member who has made important contributions and provided outstanding service to the association and the swine industry.

Dr Main obtained his DVM from the Iowa State University (ISU) College of Veterinary Medicine in 1996. He subsequently received a PhD in nutrition from the Food Animal Health and Management Center and Department of Animal Science at Kansas State University in 2005. He began his veterinary career as a staff veterinarian in the Murphy-Brown Western Operations. He became the company's director of production systems in 2003. In that role he led research to improve production and health in the largest pig production company in the world.

In 2009, he accepted a position managing the ISU Veterinary Diagnostic Laboratory (VDL) where he is currently professor and director of operations. The ISU VDL team of 145 faculty and staff process more than 80,000 case submissions and conduct approximately 1.5 million diagnostic assays annually. Under his leadership, the ISU VDL has seen significant growth and continued its long history of providing a customer-centric service to swine veterinarians throughout the United States.

Dr Main has been heavily involved with the AASV and National Pork Board (NPB) throughout his career, on committees such as the AASV Foreign Animal Disease Committee, NPB Porcine Epidemic Diarrhea Virus Taskforce, NPB Emerging Disease Surveillance Data Management Taskforce, Swine Health Information Center Surveillance Data Working Group, and several others. Dr Main has been recognized for his efforts with several awards, including the Honorary Master Pork Producer from the Iowa Pork Producers Association, the National Pork Producer Award for Innovative Research, the Alpha Gamma Rho alumni achievement award, and the Allen D. Leman Science in Practice Award.

When asked what it meant to him to receive the Howard Dunne Memorial Award he responded, "I am deeply humbled and honored to be recognized by this organization, whose members have had such a positive impact on my life. I feel incredibly blessed to have had so many tremendous mentors, coworkers, clients, and an overly understanding and supportive spouse. I am most appreciative in that this honor is an outward recognition of appreciation for the tremendous group of people that I have the opportunity to work with and serve each day."

Dr Main and his wife, Marcy, live in Ames, Iowa.

## Meritorious Service Award

**Dr Jeffrey Harker** was named the **Meritorious Service Award** recipient.The award recognizes individuals who have provided outstanding service to the AASV.

Dr Harker grew up on a diversified livestock and grain farm in south central Indiana. His father built one of the first confinement swine barns in the community in 1980. Interacting with the veterinarians who visited their farm stimulated an interest in population medicine and becoming a veterinarian. Dr Harker was accepted to veterinary school at Purdue University in 1990.

After graduation from veterinary school in 1994, Dr Harker joined Dr Max Rodibaugh at Swine Health Services as an associate veterinarian and then became a partner in 2001. Their practice is dedicated to swine, and serves a very diverse swine clientele ranging from small show-pig herds to contract growers in integrated production. The bulk of their clients have independent family farms.

Dr Harker has been involved in many organizations, starting with 4-H club president and FFA chapter president. He also received the American Farmer Degree from the FFA. He served 7 years on the Indiana Pork Producers Board of Directors and was president in 2008. Dr Harker currently serves as AASV District 4 director and represents AASV in the American Veterinary Medical Association's House of Delegates. He has also served on the AASV Annual Meeting Planning Committee and currently chairs the AASV Continuing Education Committee. Dr Harker has been involved with the National Pork Board's Operation Main Street program since it began several years ago.

When asked to comment about receiving the award, Harker responded, "I really appreciate being recognized by my peers at AASV. This organization has benefited me my whole career and I continue working to pay back what I have gained by membership in this great organization."

Dr Harker and his wife, Traci, reside in Frankfort, Indiana. They have four children: Kathleen, Sarah, Matthew, and Amelia.


Dr Rodger Main, recipient of the Howard Dunne Memorial Award


Dr Jeffrey Harker, recipient of the AASV Meritorious Service Award

## Young Swine Veterinarian of the Year Award

The **Young Swine Veterinarian of the Year Award** was presented to **Dr Josh Ellingson**. It is given annually to an AASV member 5 or fewer years post graduation who has demonstrated the ideals of exemplary service and proficiency early in his or her career.

Dr Ellingson received his DVM degree in 2011 from Iowa State University (ISU) College of Veterinary Medicine. He received a master's degree in Veterinary Microbiology from ISU in 2013.

Dr Ellingson is currently a partner and veterinarian with AMVC Management Services in Audubon, Iowa. In addition to his work with AMVC, he is the associate director and serves on the board of directors of the Swine Medicine Education Center at ISU's College of Veterinary Medicine.

Dr Ellingson grew up in Alden, Iowa, on a swine and row crop farm, where his parents, Scott and Cynthia, still live. It was there he developed an appreciation for animals, agriculture, farmers, and rural communities. Throughout his education he developed a passion for the sciences and therefore sought out a career which combined these interests.

"I was looking for a career that would incorporate agriculture, the sciences, and something where I'd be able to help people.


Dr Josh Ellingson, recipient of the AASV Young Swine Veterinarian of the Year Award

Veterinary medicine has provided the means for me to do those things. Swine medicine is a great combination of animal husbandry, hardcore sciences (microbiology, virology, chemistry, etc), and working with people," noted Dr Ellingson.

Upon acceptance of the award, Dr Ellingson commented, "I'm humbled to be honored with this award. I credit my family, the AMVC team, and all of the mentors who have helped me along the way, especially the other veterinarians at AMVC and those associated with the Swine Medicine Education Center. I get to work with great people every day whom I consider to be my extended family. Thank you to AASV for providing such great avenues to develop professional skills and knowledge."

Dr Ellingson and his wife, Jennifer, reside in Audubon, Iowa, and currently have two children, Tyler (5) and Carly (3), and a miniature dachshund.

## Technical Services/Allied Industry Veterinarian of the Year Award

**Dr Thomas Wetzell** received the **Technical Services/Allied Industry Veterinarian of the Year Award**. Established in 2008, the award recognizes swine industry veterinarians who have demonstrated an unusual degree of proficiency and effectiveness in delivery of veterinary service to their companies and their clients, as well as given tirelessly in service to the AASV and the swine industry.

Dr Wetzell was recognized for his years in technical service at Boehringer Ingelheim Vetmedica (BI). Dr Wetzell joined BI in 2008 as part of their US swine professional services team and works with swine veterinary practices and production companies in the upper Midwest. He graduated with his DVM from the University of Minnesota in 1977, and practiced with his father in Wells, Minnesota, prior to joining BI. Dr Wetzell, AASV's 2004 Swine Practitioner of the Year, served as president of both South Central Veterinary Associates and South Central Ag Products.

When asked to comment on what the award meant to him, Dr Wetzell said, "It is an honor yet very humbling to receive this award in a field that has so many deserving veterinarians."

Dr Wetzell and his wife, Pam, reside in Cleveland, Minnesota.


Dr Thomas Wetzell, recipient of the AASV Technical Services/Allied Industry Veterinarian of the Year Award

## Annual Business Breakfast

American Association of Swine Veterinarians President Dr George Charbonneau reported on the association's membership and activities during the annual breakfast on Tuesday, February 28th. He stated there were 1452 members, including 327 student members. The 2017 AASV officers, Drs Alex Ramirez, President; Scanlon Daniels, President-elect; Nathan Winkelman, Vice President; and George Charbonneau, Past President, were introduced. The board welcomed newly re-elected district directors: Dr Gene Nemechek (District 2), Dr Bill Hollis (District 5), Dr Jeff Kurt (District 9), and Dr Blaine Tully (District 11). Dr Charbonneau also welcomed Jordan Gebhardt (Kansas State University), incoming Alternate Student Delegate to the AASV Board of Directors, and thanked outgoing Student Delegate Emily Mahan-Riggs (North Carolina State University). Brent Sexton (Iowa State University) assumes the role of Student Delegate. Honored guests at the business breakfast included Dr Tom Meyer (AVMA president), Dr John Howe (AVMA Executive Board representative), Dr Liz Wagstrom (National Pork Producers Council), and Dr Patrick Webb (National Pork Board). The audience heard updates from each respective organization. Approximately 300 people attended the breakfast.

# AASV Foundation announces student scholarships

The American Association of Swine Veterinarians Foundation awarded scholarships totaling $25,000 to 15 veterinary students.

**Cassandra Fitzgerald**, Iowa State University, received the $5000 scholarship for top student presentation. Her presentation was titled "Comparison of standard and bench entry protocols for prevention of environmental contamination due to personnel entry in a commercial swine facility." Zoetis provided the financial support for the **Top Student Presenter Award**.

Additional scholarships totaling $20,000 were funded by Elanco Animal Health as shown in the accompanying photos.

Fifty veterinary students from 12 universities submitted abstracts for consideration. From those submissions, 15 students were selected to present during the annual meeting. Zoetis, sponsor of the Student Seminar, provided a $750 travel stipend to each student selected to participate.

Kim Lawson (far right) presented scholarships sponsored by Elanco Animal Health. Recipients of the $2500 AASV Foundation scholarships (from left): Megan Nickel, Iowa State University; Zhen Yang, University of Minnesota; Michael Mardesen, Iowa State University; Kimberlee Baker, Iowa State University.

Kim Lawson (far right) presented scholarships sponsored by Elanco Animal Health. Recipients of the $1500 AASV Foundation scholarships (from left): Alyssa Anderson, University of Minnesota; Kylie Glisson, North Carolina State University; Hunter Baldry, University of Minnesota; Chelsea Ruston, Iowa State University; and Jane Newman, University of Guelph.

Recipient of the $5000 scholarship for Top Student Presenter during AASV's Student Seminar: Cassandra Fitzgerald, Iowa State University. Pictured with Christine is Dr Lucina Galina (left) of Zoetis, sponsor of the Student Seminar and Top Student Presenter Award.

Kim Lawson (far right) presented scholarships sponsored by Elanco Animal Health. Recipients of the $500 AASV Foundation scholarships (from left): Rachel Schulte, Iowa State University; Megan Pieters, Iowa State University; Chris Deegan, University of Minnesota; Olivia Myers, North Carolina State University. Not pictured: Allison Knox, University of Illinois.

# AASV announces student poster competition awardees

The American Association of Swine Veterinarians (AASV) provided an opportunity for 15 veterinary students to compete for awards in the Veterinary Student Poster Competition. Newport Laboratories sponsored the competition, offering awards totaling $4000.

On the basis of scores received in the original judging of abstracts submitted for the AASV Student Seminar, the top 15 abstracts not selected for oral presentation at the annual meeting are eligible to compete in the poster competition.

Newport Laboratories announced the following awards during the AASV Luncheon on February 27th:

$500 scholarship: **Jordan Gebhardt**, Kansas State University – Top student poster entitled "Evaluation of the effects of flushing feed manufacturing equipment with chemically treated rice hulls on porcine epidemic diarrhea virus (PEDV) cross contamination during feed manufacturing."

$400 scholarships: **Taylor Engle**, Virginia-Maryland Regional CVM; **Eve Fontanella**, Iowa State University. Not pictured.

$300 scholarships: **Sara Hamlett**, Iowa State University; **Joel Steckelberg**, Iowa State University; **Courtney Wright**, Ohio State University.

$200 scholarships: **Jessica Applebaum**, University of Pennsylvania; **Megan Bloemer**, University of Illinois; **Brandi Burton**, University of Illinois; **Laura Constance**, Kansas State University; **Donna Drebes**, University of Minnesota; **Anna Martin**, University of Pennsylvania; **Katie O'Brien**, University of Illinois; **Lauren Redies**, University of Saskatchewan; **Rochelle Warner**, Iowa State University.

In addition to the poster competition awards, each student poster participant received a $250 travel stipend from Zoetis and the AASV.

Jordan Gebhardt, Kansas State University winner of the $500 scholarship for top student poster.

The $300 poster competition winners (left to right): Sara Hamlett, Iowa State University; Joel Steckelberg, Iowa State University; and Courtney Wright, Ohio State University.

The $200 poster competition winners (left to right): Jessica Applebaum, University of Pennsylvania; Donna Drebes, University of Minnesota; Laura Constance, Kansas State University; Anna Martin, University of Pennsylvania; Brandi Burton, University of Illinois; Megan Bloemer, University of Illinois; Rochelle Warner, Iowa State University. Not pictured: Katie O'Brien, University of Illinois and Lauren Redies, University of Saskatchewan.

# AASV Proceedings online

Even if you weren't able to attend the AASV Annual Meeting in Denver, you can still benefit from the many excellent presentations delivered at the meeting. The conference proceedings (including the pre-conference seminar booklets) are available for all AASV members to download at **https://www.aasv.org/library/proceedings/** (or look under the "Resources" menu tab on the AASV Web site for "AASV Meeting Proceedings"). All you need is your AASV member username and password with 2017 dues-paid status.

Here's what you'll find:

- The "big book" containing all of the papers for the regular meeting sessions in a single PDF file with a hyperlinked table of contents
- Seminar booklets – a PDF file for each seminar
- Individual papers for each presentation in the Swine Information Library (**https://www.aasv.org/library/swineinfo/**).

If your AASV username/password isn't handy, click the "Reset Password" link in the upper right of an AASV Web page to have it e-mailed to you. Need to pay your 2017 AASV membership dues? Go to **http://ecom.aasv.org/membership**. Please allow a few days for your membership record to be updated.

# Thank you, AASV Annual Meeting sponsors!

Members of AASV attending the annual meeting make a substantial investment in the form of registration fees, travel, lodging, meals, and potential loss of income while away from work. However, the cost of attendance would be even greater – or the quality of the meeting experience reduced – if it were not for the financial support provided by corporate sponsors for refreshments, meals, and social activities, as well as scholarships and travel stipends for veterinary students. The AASV extends its sincere appreciation for the sponsorship of meeting events by the following companies:

- **AgriLabs** (Refreshment Break)
- **Boehringer Ingelheim Vetmedica, Inc** (AASV Luncheon)
- **CEVA Animal Health** (Refreshment Break)
- **Elanco Animal Health** (AASV Awards Reception and AASV Foundation Veterinary Student Scholarships)
- **GlobalVetLINK** (Refreshment Break)
- **Hog Slat** (Refreshment Break)
- **Merck Animal Health** (Student Reception, Student Swine Trivia Event, Merck Veterinary Student Scholarships)
- **Newport Laboratories** (Veterinary Student Travel Stipends and Veterinary Student Poster Scholarships)
- **Quality Technology International** (Refreshment Break)
- **Stuart Products** (Praise Breakfast)
- **Zoetis** (Welcome Reception, AASV Student Seminar and Student Poster Session, AASV Foundation Top Student Presenter Scholarship)

The AASV is also grateful to the 91 companies and organizations that provided support through their participation in the 2017 Technical Tables exhibit.

**Thank you all!**

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# One Passion for Pigs


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SWINE VETERINARIANS


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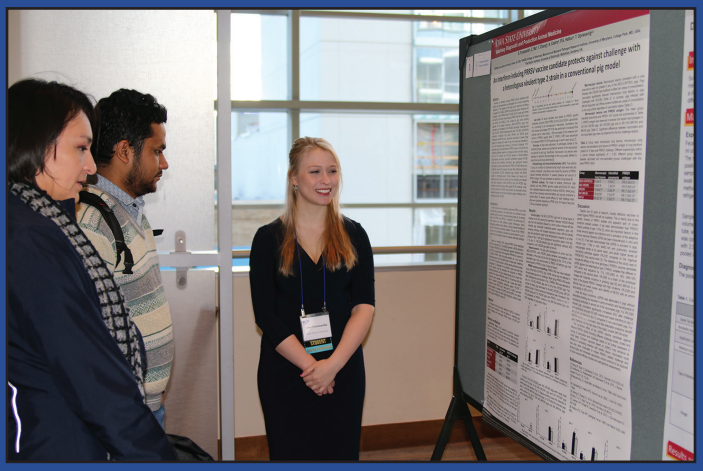





START HEALTHY. END STRONG.

Boehringer Ingelheim

# FOUNDATION NEWS

## Five receive AASV Foundation-Merck Veterinary Student Scholarships

The AASV Foundation awarded $5000 scholarships to each of five veterinary students at the 2017 AASV Annual Meeting in Denver. The AASVF-Merck Veterinary Student Scholarships were funded by a $25,000 contribution from Merck Animal Health in an effort to identify and assist future swine veterinarians with their educational expenses. This was the second year for the scholarship program.

The 2017 scholarship recipients are

- Kayla Blake, Auburn University
- Jordan Gebhardt, Kansas State University
- Allison Knox, University of Illinois
- Chelsea Ruston, Iowa State University
- Brent Sexton, Iowa State University

Dr Norm Stewart (far left), and Dr Jack Creel (far right), representing Merck Animal Health, presented $5000 scholarships to (from left), Brent Sexton, Iowa State University; Jordan Gebhardt, Kansas State University; Chelsea Ruston, Iowa State University. Not pictured are scholarship recipients Kayla Blake, Auburn University, and Allison Knox, University of Illinois.

Second- and third-year veterinary students enrolled in AVMA-accredited or -recognized colleges of veterinary medicine in the United States, Canada, Mexico, South America, and the Caribbean islands were eligible to apply. A committee of four, consisting of two AASV Foundation Board members and two AASV members-at-large, reviewed the applications to select the five recipients from the pool of 46 applications submitted for consideration.

## AASV Foundation accepting applications for ACAW scholarship

The AASV Foundation Board of Directors is now accepting applications from AASV members seeking board certification in the American College of Animal Welfare (ACAW). The applicant must have a DVM or VMD degree and at least 5 years of continuous membership in the AASV.

To apply, the applicant must submit a curriculum vitae, an ACAW-approved program plan, and three (3) letters of reference (one of which must come from the applicant's mentor). There is no submission "due date," but there is a limit to the amount of funding available each year. A selection committee will review applications as they are received.

The scholarship will provide annual reimbursements for actual expenses related to the ACAW program, including travel, course fees, and textbooks, with a maximum reimbursement amount of $20,000. Reimbursement will not cover lost income. An incentive payment of $10,000 will be issued upon successful and timely completion of the ACAW Board Certification.

For more information, contact the AASV office: Tel: 515-465-5255; E-mail: **aasv@aasv.org**.

# Foundation endowment grows with addition of two Legacy Funds

During the recent AASV Foundation Luncheon in Denver, foundation chairman Dr John Waddell announced the establishment of two new Legacy Funds. The Legacy Fund represents the highest level of the foundation's triad of endowed giving programs (Leman-Heritage-Legacy), with a minimum $50,000 contribution required to establish a named endowment.

The **Pipestone Veterinary Services Practice Legacy Fund** is the first Legacy Fund to be established by a veterinary practice. In designating the fund proceeds to support education and long-range issues of the profession, Pipestone Holdings Chair Dr Gordon Spronk noted that "The swine veterinary profession and US swine industry face many issues now and in the future. The AASV Foundation (and proceeds of this Practice Legacy Fund) will support finding long-term solutions to maintaining the US swine industry as the best in the world." He added, "We hope that the small role we play encourages other practices to support the AASV Foundation via a swine practice Legacy Fund."

A firm belief in the value of higher education and an admiration for the AASV Foundation's work assisting veterinary student participation in AASV led Dr K. T. Wright to create the **Dr Kenneth T. Wright Legacy Fund.** When asked why he chose to participate in the Legacy program, he answered, "Over the years, I have asked many AASV members to participate in the foundation as Leman or Heritage Fellows, and I'm a firm believer in the old adage to 'put your money where your mouth is.' Veterinary medicine has been very good to me during my career, with the majority of the practice work being involved with swine, and I considered creating a Legacy Fund as a worthy way of giving back." In addition to his participation as an AASV Foundation board member and donor, Dr Wright and his wife Betty have endowed numerous scholarships at Western Illinois University and the University of Illinois.

The foundation board created the Legacy program in 2014 to provide an opportunity to recognize a principal donor – or an honoree – through a significant contribution. The foundation's first Legacy Fund was established in 2016 by Dr Nathan L. Winkelman.

A donor (or multiple donors) may establish and name a Legacy Fund with a gift of $50,000 or more. The fund may be named after the donor or another individual or group. As an endowed giving program, Legacy Fund contributions are invested to generate income in the form of interest, dividends, and capital gains. The income is used to fund foundation activities, while the original contribution is conserved, helping to assure the organization's long-term stability and success. The Legacy Fund donor has the opportunity to designate which of three foundation mission categories the fund proceeds will support: 1) research, 2) education, or 3) long-range issues.

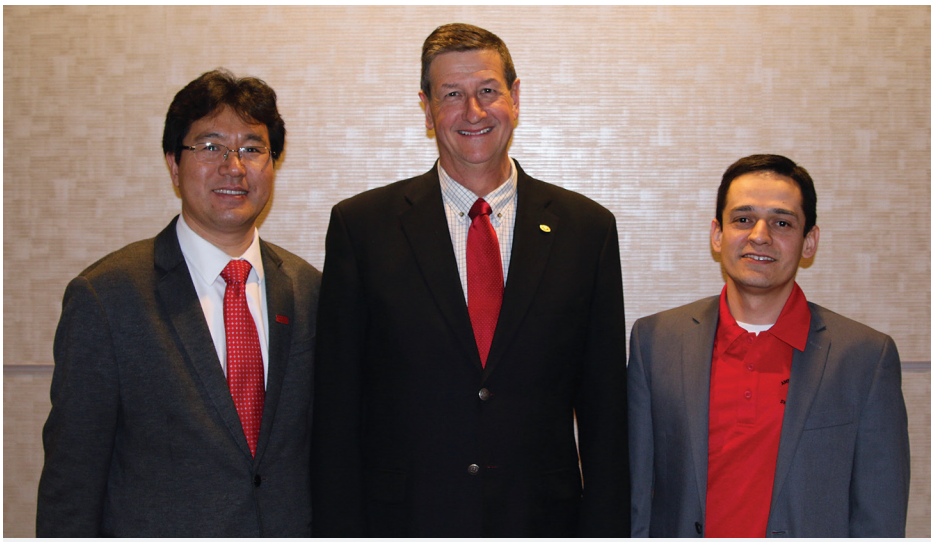
The AASV Foundation has set a goal to establish a $2 million endowment by the 2019 celebration of AASV's 50th anniversary, while at the same time maintaining its ongoing commitment to fund research, scholarships, externships, tuition grants, and other programs and activities that benefit the profession of swine veterinary medicine. For more information about the AASV Foundation, see **www.aasv.org/foundation**.

AASV Foundation Chairman Dr John Waddell recognizes and thanks Dr K. T. Wright for establishing the Dr Kenneth T. Wright Legacy Fund.

AASV Foundation Chairman Dr John Waddell recognizes and thanks Dr Joel Nerem, representing Pipestone Veterinary Services, for establishing the Pipestone Veterinary Services Practice Legacy Fund.

# PRRSV research selected for funding in 2017

Dr John Waddell, chairman of the AASV Foundation, announced the selection of two research proposals, both of which focus on the porcine reproductive and respiratory syndrome virus (PRRSV), for funding in 2017. The announcement was made on February 26 during the foundation's annual luncheon in Denver, Colorado.



Dr John Waddell with Dr Jianqiang Zhang (left) and Dr Daniel Linhares (right) whose research proposals have been selected for funding by the AASV Foundation.

A grant of $30,000 was awarded to Dr Jianqiang Zhang and co-investigators at Iowa State University to fund the project "Comparison of PRRSV isolation in different cell lines towards improving success of isolating PRRSV from clinical samples." The study will use serum, lung, and oral-fluid samples to compare the use of two different cell lines for virus isolation. The project will also evaluate the correlation of PRRSV concentration, genetic lineage, and specimen type to virus isolation success. The goal is to improve the success of PRRSV isolation attempts when requested by swine practitioners for autogenous vaccine production or further characterization.

Dr Daniel Linhares at Iowa State University (ISU), along with co-investigators at ISU and Carthage Veterinary Service Ltd, was awarded a grant of $11,824 to investigate the effect of attenuated PRRSV on short-term and long-term whole-herd productivity. The primary objective of the study is to investigate and measure the impact of modified live vaccine (MLV) on key breeding-herd performance parameters, using natural experiments under field conditions. It is anticipated this information will be used with existing economic models to assist swine veterinarians in making informed decisions regarding the use of PRRSV MLV vaccine as a preventive tool.

Dr Nathan Winkelman chaired the scientific subcommittee responsible for reviewing and scoring the proposals received for consideration, and he joins the foundation in thanking Drs John Baker, Tim Blackwell, Peggy Anne Hawkins, Martin Mohr, and Jerry Torrison for their service on the subcommittee.

An overview of past and current projects funded by the foundation is available at **https://www.aasv.org/foundation/research.htm**. The foundation will issue its next call for research proposals in the fall of 2017.

# Foundation auction benefits Ethiopian charity as well as swine veterinarians

The 2017 American Association of Swine Veterinarians (AASV) Foundation held its annual fundraising auction on February 27 during the 48th AASV Annual Meeting in Denver, Colorado. This year's auction raised $112,666!

The funds raised during the auction support foundation programs, including student travel stipends, research projects, scholarships, student externships, awards, support for veterinarians pursuing board certification in the American College of Animal Welfare, and other opportunities to enhance the personal and professional aspects of swine veterinary medicine.

One of the highlights of the auction was the generosity of the AASV Foundation 2017 Consortium. This ad hoc group of 32 individuals and organizations raised $32,000 for the foundation. And, thanks to Pipestone Veterinary Services' matching contribution, Adams Thermal Foundation-Ethiopia also received $32,000 to support the fight against hunger and promote childhood education in Ethiopia. Adams Thermal Foundation operates two schools in Ethiopia enrolling the "poorest of the poor" – children who are orphaned or HIV-positive or who struggle from the effects of extreme poverty. Adams Thermal Academies enroll 900 students from kindergarten through grade 10. Children receive an exceptional education, clothing, textbooks and school materials, food, medical attention, and transportation.

Auctioneers Dr Tom Burkgren (AASV Executive Director) and Dr Shamus Brown called the auction, assisted by Wes Johnson, who generously lent his capable clerking


Zach and Ashley Brinkman pose by the chainsaw carving donated by Newport Laboratories. Dr Paul Armbrecht purchased the carving with his winning bid of $2,425.

## AASVF 2017 Consortium

Paul Armbrecht
Butch and Emma Baker
John and Andrea Baker and family (Warrick Veterinary Clinic)
Bob Blomme
Dave Bomgaars
Ron Brodersen
Dyneah Classen
Joe Connor
Wayne Freese
GlobalVetLINK
Doug Groth
Pat Halbur
Steve Henry
Howard Hill
Tyler Holck
Bill Hollis
Kerry Keffaber
Hans Koehnk
Aaron Lower
NutriQuest
Daryl Olsen
Jodie Pettit
David Reeves
Max Rodibaugh
Hans Rotto
Steve Schmitz
Peter Schneider
Mike and Lisa Tokach
Veterinary Medical Center
John Waddell
Thomas Wetzell
Warren Wilson

Thanks to the consortium and Pipestone Veterinary Services for their generous donation!


AASV Foundation Chairman Dr John Waddell and AASVF Auction Committee Chairman Dr R. B. "Butch" Baker pause while checking out the silent-auction bidding status displayed on the leaderboard behind them. For the first time, bidding on the silent auction was paperless, with all bids submitted electronically via ClickBid Mobile Bidding. The 57 silent-auction items brought $17,340.

services to the dynamic duo. The spirited live auction raised $84,825. This was in addition to the $17,340 collected during the silent auction and $10,501 in generous cash donations. The foundation thanks all those who participated in the auction by bidding on or donating items, as well as those who served on the auction committee chaired by Dr Butch Baker. Visit **https://www.aasv.org/foundation/2017/auctionlist.php** to view auction results.

A special thanks goes to the bid-takers: Miranda Ayers, Dave Bomgaars, Joel Burkgren, Peggy Anne Hawkins, Howard Hill, Terry Metcalf, David Reeves, Max Rodibaugh, and John Waddell, who kept the bids coming while modeling blue grilling aprons that were later sold to the highest bidders. In addition, the following folks' behind-the-scenes and front-end help was invaluable: Miranda Ayers, Joel Burkgren, Sue Kimpston, Kay Kimpston-Burkgren, David and Karen Menz, Karen Richardson, Lee and Sue Schulteis, Tina Smith, and Harry Snelson.

# AASV Foundation Auction buyers

The AASV Foundation Auction Committee is grateful to everyone who made a contribution or bid on items in the live and silent auctions. Thanks to your support, the foundation raised $112,666! We are pleased to recognize the bidders listed below who purchased one or more items at the auction.

Matt Anderson
Mike Apley
Paul Armbrecht
John and Andrea Baker
Brett Bonwell
Mark Brinkman
Laura Bruner
George Charbonneau
Scanlon Daniels
Mark Engesser
Phil Gauger
Christa Goodell
Doug Groth
Peggy Anne Hawkins
Dale Hendrickson
Bill Hollis
Clark Huinker
Kerry Keffaber
Paul Knoernschild
Chris Kuster
Duane Long
Rodger Main
Daniel McManus
Dale Mechler
Luke Minion
Bill Minton
Elizabeth Newton-Royer
Daryl Olsen
Brent Pepin
Michael Pierdon
Chad Pilcher
Doug Powers
Brian Roggow
Michael Schelkopf
Steve Schmitz
Peter Schneider
Kent Schwartz
Mike Senn
Katie Sinclair
Paul Sundberg
Debra Thompson
James Unwin
Dennis Villani
Drew Weir
Ron White
Warren and Marilyn Wilson
Nathan Winkelman
Barry Wiseman
Teddi Wolff
Katie Woodard

# Committees meet in Denver

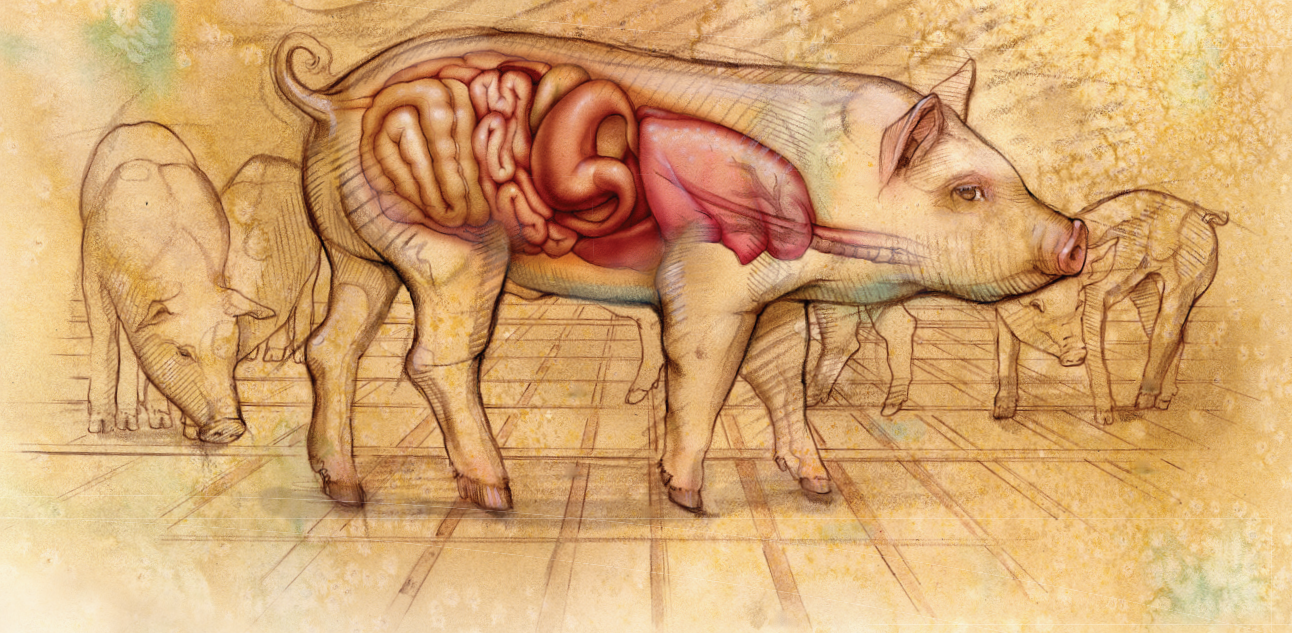
Thirteen issue-based committees met during the 2017 American Association of Swine Veterinarians (AASV) 48th Annual Meeting in Denver, Colorado. The AASV Board of Directors establishes the committees to address specific issues associated with swine veterinary medicine and provide recommendations for actions to the AASV leadership. In addition to being an integral part of the leadership structure within AASV, the committees also serve as a great way for members to participate in developing positions for the association, learn about a particular issue, and meet other members. Over 190 AASV members volunteer to serve on at least one committee. That's a lot of experience focused on the issues of swine health, well-being, and production.

The following are some key highlights from the committee meetings:

- The **Nutrition Committee** discussed the implementation of the recent changes to the Veterinary Feed Directive from the perspective of the feed manufacturers, veterinarians, and nutritionists. Overall, it appears the process has gone pretty smoothly, with most of the challenges logistic in nature. The committee also considered reports on increasing uterine prolapses possibly tied to mycotoxins. There is an on-going study to further evaluate potential etiologies.
- The **Student Recruitment Committee** is requesting funding from the AASV board to continue hosting the Swine Medicine Talks series, along with the Iowa State University College of Veterinary Medicine (ISU CVM) Swine Medicine Education Center and the ISU CVM AASV Student Chapter. The Swine Medicine Talks is a three-part live-streamed lecture series with expert speakers representing a wide range of topics.
- The **Boar Stud Committee** is forming an ad hoc working group in collaboration with the Pig Welfare Committee to consider recommendations for the humane euthanasia of large boars, cull boar transportation concerns, and stall sizes to accommodate today's commercial boars.
- The **Influenza Committee** is emphasizing the importance of continued participation in the USDA's Influenza Surveillance Program by all swine veterinarians and National Animal Health Laboratory Network laboratories. In addition, the committee formed two working groups. The Surveillance Working Group will work with the USDA Animal and Plant Health Inspection Service to promote and facilitate obtaining influenza A viruses from the USDA National Veterinary Services Laboratory repository for use as diagnostic reagents and vaccine candidates, and for research purposes and to increase AASV membership awareness of the repository. The Vaccine Working Group will consider making recommendations on vaccines for show pigs.
- The focus of the **Communications Committee** in 2017 is on encouraging increased membership use of the student podcasts posted on the AASV Web site and is continuing to work with the ISU Swine Medicine Education Center to improve the AASV Image Library.
- The **Committee on Transboundary and Emerging Diseases** (CTED) met for the first time at the annual meeting. Following the 2016 annual meeting, the AASV Board combined the Foreign Animal Disease and Swine Health Committees to form the CTED. The committee is planning to focus attention on the issue of maintaining business continuity in the face of a foreign animal disease (FAD) outbreak. To this end, the committee members expressed support for the validation of oral fluids for FAD diagnostics, the formation of a Business Continuity Guidance Group to promote the overall business continuity plan, and continued input into the Secure Pork Supply Risk Assessment process.
- The **Human Health and Safety Committee** established three objectives for 2017: to increase awareness among the AASV membership of the top public health topics of concern as identified by the committee, to develop and provide educational and awareness materials to the AASV membership on best practices for minimizing influenza transmission, and to promote active membership and attendance at the 2018 Human Health and Safety Committee meeting.
- The **Operation Main Street** (OMS) Committee encourages more AASV veterinarians to become OMS trained and participate in the program, which makes veterinarians available to academic and civic groups for presentations describing modern swine production. The OMS coordinators will be focusing on meeting with groups such as dieticians, managers of school nutrition programs, state grocery associations, and food wholesalers in 2017.
- The **Production Animal Disease Risk Assessment Program (PADRAP) Advisory Committee** noted that the attendance at this year's training session on Saturday morning was the largest ever, with over 25 participants "sitting in" to learn about the program. While over 40% of the US breeding herd has been assessed at least once, current use of the program is low. The committee is trying to find additional funding sources to support PADRAP going forward.

*Advocacy in action continued on page 161*

# GOING WHOLE HOG



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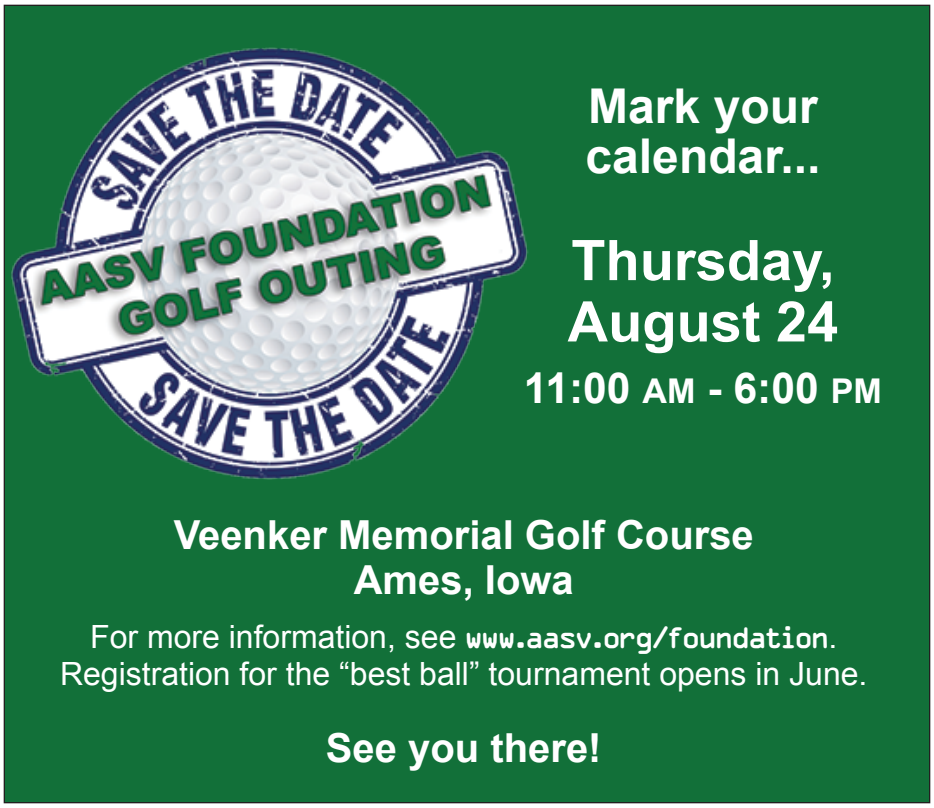
*Advocacy in action continued from page 159*

- The **Pharmaceutical Issues Committee** was particularly busy this year considering the development of an antibiotic database as a resource for AASV members, offering direction into the formation of comments in response to the Food and Drug Administration's effort to establish durations of use for medically important antibiotics, exploring the issue of antibiotic use in young piglets, and providing some guidance on the development of a document describing prevention use of antibiotics. In addition, the committee formed a working group to attempt to define prevention uses of antibiotics in swine medicine.
- The **Pork Safety Committee** discussed the recent outbreak of salmonellosis in Washington state, physical hazards in pork, and the need to raise awareness of the AASV membership regarding the potential risk associated with toxoplasmosis.
- The main initiative of the **Porcine Reproductive and Respiratory Syndrome (PRRS) Task Force** continues to be the development of the PRRS virus (PRRSV) Eradication framework document. The next step includes sharing the document with other committees and then identifying a region or area willing to review the document and, ideally, pilot it to determine its effectiveness and identify additional gaps. The task force will also work on developing "guidance documents" describing how to achieve some of the points left undefined in the framework document.
- The **Pig Welfare Committee** developed three working groups to 1) work with the Boar Stud Committee on boar-associated welfare issues, 2) evaluate whether a wording adjustment on the sow housing position statement is necessary to specifically address farrowing stalls for sows and suckling piglets, and 3) develop "guidelines of success" for producers and companies who are considering moving to antibiotic-free production.

The committees are an integral part of the AASV leadership and we appreciate all the efforts of the volunteer members. If you are interested in learning more about the committee activities, visit the committee Web pages on the AASV Web site (**https://www.aasv.org/members/only/committee/**). Contact the committee chair or the AASV office to join a committee.

Harry Snelson, DVM
Director of Communications



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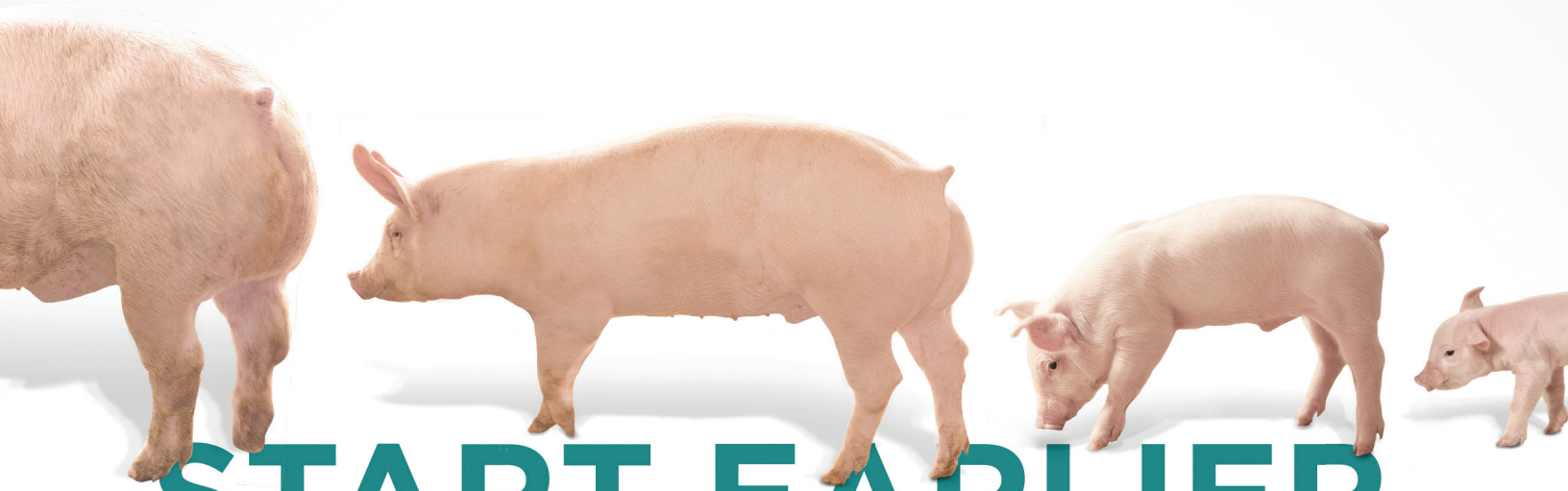

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2 Versus non-vaccinated pigs



9/16 SW-55269-2

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# Upcoming meetings

## 8th International Conference on Emerging Zoonoses

May 7-10, 2017 (Sun-Wed)
Manhattan, Kansas

For more information:
Target Conferences Ltd, 65 Derech Menachem Begin
PO Box 51227, Tel Aviv, 6713818 ISRAEL
Tel: +972 3 5175150; Fax: +972 3 5175155
E-mail: zoo@target-conferences.com
Web: http://www.zoonoses-conferences.com/

## UK-based series of workshops on conducting systematic reviews and meta-analysis

May 29-June 2, 2017 (Mon-Fri)
University of York, Heslington, York YO10 5DD.

Introduction to systematic reviews for food and feed related topics:
May 29-31, 2017

Meta-analysis in systematic reviews for food and feed related topics:
June 1-2, 2017

For more information and registration:
Annette O'Connor
Lloyd Vet Med Center Rm 2424
College of Veterinary Medicine, Iowa State University
1809 S Riverside Drive, Ames, IA 50011-3619
Tel: 515-520-2376
E-mail: oconnor@iastate.edu
Web: http://www.yhec.co.uk/training/introduction-to-systematic-reviews-for-food-and-feed-related-topics/

## World Pork Expo

June 7-9, 2017 (Wed-Fri)
Iowa State Fairgrounds, Des Moines, Iowa

Hosted by the National Pork Producers Council

For more information:
National Pork Producers Council
10676 Justin Drive, Urbandale, IA 50322
Web: http://www.worldpork.org

## US-based series of workshops on conducting systematic reviews and meta-analysis

June 26-30, 2017 (Mon-Fri)
College of Veterinary Medicine, Iowa State University, Ames, Iowa

Introduction to systematic reviews in food and feed related topics:
June 26-28, 2017

Meta-analysis in systematic reviews in food and feed related topics:
June 29-30, 2017

For more information and registration:
Annette O'Connor
Lloyd Vet Med Center Rm 2424
College of Veterinary Medicine, Iowa State University
1809 S Riverside Drive, Ames, IA 50011-3619
Tel: 515-520-2376
E-mail: oconnor@iastate.edu
Web: http://register.extension.iastate.edu/systematic

## Allen D Leman Swine Conference

September 16-19, 2017 (Sat-Tue)
Saint Paul RiverCentre, Saint Paul, Minnesota

For program information:
Tel: 612-624-4972
E-mail: cceconf4@umn.edu
Web: http://cceevents.umn.edu/allen-d-leman-swine-conference

For registration information:
Tel: 612-625-2900
E-mail: ccereg@umn.edu
Web: http://cceevents.umn.edu/allen-d-leman-swine-conference

## US Animal Health Association 121st Annual Meeting

October 12-18, 2017 (Thu-Wed)
Town and Country Hotel, San Diego, California

For more information:
Web: http://www.usaha.org

## American Association of Swine Veterinarians 49th Annual Meeting

March 3-6, 2018 (Sat-Tue)
Manchester Grand Hyatt, San Diego, California

For more information:
American Association of Swine Veterinarians
830 26th Street, Perry, IA 50220-2328
Tel: 515-465-5255
E-mail: aasv@aasv.org
Web: http://www.aasv.org/annmtg

## 25th International Pig Veterinary Society Congress

June 11-14, 2018 (Mon-Thu)
Chongqing, China

For more information:
Web: http://www.ipvs2018.net/

**For additional information on upcoming meetings: https://www.aasv.org/meetings/**

# Photo Corner

A Missouri sow

*Photo courtesy of Tina Smith*