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# JOURNAL OF SWINE HEALTH AND PRODUCTION

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## JSHAP SPOTLIGHT

### Dr Andréia Arruda

**The Ohio State University**

Dr Arruda earned a DVM ('10) from Sao Paulo State University, an MS ('12) from University of Minnesota, and a PhD ('15) from University of Guelph. Dr Arruda is an Assistant Professor at The Ohio State University where she teaches veterinary and graduate students, conducts research, and serves the scientific community. Her research area of interest is the transmission of infectious diseases in swine but is also involved in projects related to multiple species and public health due to her epidemiology expertise. Dr Arruda is honored to serve on the JSHAP Editorial Board and help select high-quality papers for publication, knowing that manuscripts will be read, and the information applied by many influential swine-related professionals around the world.

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**Important Safety Information:** Available under prescription only. AIVLOSIN is indicated for control of porcine proliferative enteropathy (PPE) associated with *Lawsonia intracellularis* infection in groups of swine intended for slaughter in buildings experiencing an outbreak of PPE. Control of swine respiratory disease (SRD) associated with *Bordetella bronchiseptica, Haemophilus parasuis, Pasteurella multocida, Streptococcus suis,* and *Mycoplasma hyopneumoniae* in groups of swine intended for slaughter in buildings experiencing an outbreak of SRD.

For use only in drinking water of pigs. Not for use in lactating or pregnant females, or males and females intended for breeding. People with known hypersensitivity to tylvalosin tartrate should avoid contact with this product. When used in accordance with label directions, no withdrawal period is required before slaughter for human consumption.



**Approved by FDA under NADA # 141-336**

AIVLOSIN®

(62.5% w/w Tylvalosin as Tylvalosin Tartrate)

**Water Soluble Granules**

**For use only in the drinking water of swine intended for slaughter.**

**Not for use in lactating or pregnant females, or males and females intended for breeding.**

**CAUTION:** Federal law restricts this drug to use by or on the order of a licensed veterinarian.

**PRODUCT DESCRIPTION:** Aivlosin® (tylvalosin tartrate) Water Soluble Granules is a water soluble granular powder for oral use by administration in the drinking water. Each gram of Aivlosin® Water Soluble Granules contains 0.625 grams of tylvalosin as tylvalosin tartrate.

**ANTIBIOTIC CLASSIFICATION:** Tylvalosin, the active ingredient in Aivlosin® Water Soluble Granules, is a macrolide antibiotic.

**INDICATIONS:** Control of porcine proliferative enteropathy (PPE) associated with *Lawsonia intracellularis* infection in groups of swine intended for slaughter in buildings experiencing an outbreak of PPE.

Control of swine respiratory disease (SRD) associated with *Bordetella bronchiseptica, Haemophilus parasuis, Pasteurella multocida, Streptococcus suis*, and *Mycoplasma hyopneumoniae* in groups of swine intended for slaughter in buildings experiencing an outbreak of SRD.

**DOSAGE AND ADMINISTRATION:** Prepare drinking water medicated with 50 parts per million tylvalosin as shown in the following table.

| Aivlosin® Water Soluble Granules sachet size | 160 grams | 400 grams |
|---|---|---|
| Tylvalosin content of sachet (grams) | 100 | 250 |
| Recommended volume of stock solution (US gallons) | 4 | 10 |
| Volume of drinking water (US gallons) | 528 | 1320 |
| Final tylvalosin inclusion rate in drinking water | 50 parts per million (ppm) | |

Administer continuously in drinking water for five (5) consecutive days. Keep water supply equipment clean and in good operating condition. Clean water medication equipment before and after each use. Do not mix or administer tylvalosin medicated water using equipment made of galvanized metal. Galvanized metal adversely affects the stability of tylvalosin in water and may reduce the effectiveness of the product. Prepare a fresh batch of medicated stock solution or medicated drinking water daily.

**MIXING DIRECTIONS:** Aivlosin® Water Soluble Granules may be mixed directly into the drinking water system or first mixed as a stock solution in a smaller amount of water, which is then added to the drinking water system, for example, using an automatic water proportioner.

Direct Mixing: When mixing the product directly into the drinking water system, the contents of the sachet should be sprinkled onto the surface of the water and mixed slowly and thoroughly for at least 3 minutes. Prepare a fresh batch of medicated drinking water daily.

Stock Solution: When preparing a stock solution, the recommended concentration is one 160 g sachet per four (4) US gallons or one 400 g sachet per 10 US gallons. Sprinkle sachet contents onto the surface of the water of the stock solution and mix slowly and thoroughly for at least 10 minutes. Use the stock solution for dilution into the drinking water system as soon as it is prepared. Add one (1) fluid ounce of this stock solution per 131 fluid ounces (1 US gallon, 3 fluid ounces) of drinking water to provide a final concentration of 50 ppm. If using an automatic water proportioner, set the flow rate to add stock solution at a rate of 1 fluid ounce per 131 fluid ounces of drinking water (1:131). Prepare a fresh batch of medicated stock solution daily.

**WARNINGS:**

**WITHDRAWAL PERIOD:** When used in accordance with label directions, no withdrawal period is required before slaughter for human consumption.

**ANTIBACTERIAL WARNINGS:** Use of antibacterial drugs in the absence of a susceptible bacterial infection is unlikely to provide benefit to treated animals and may increase the development of drug-resistant pathogenic bacteria.

**USER SAFETY WARNINGS:**

**NOT FOR USE IN HUMANS.**

**KEEP OUT OF REACH OF CHILDREN.**

May cause skin irritation. Tylvalosin tartrate has been shown to cause hypersensitivity reactions in laboratory animals. People with known hypersensitivity to tylvalosin tartrate should avoid contact with this product. In case of accidental ingestion, seek medical advice. When handling Aivlosin® Water Soluble Granules and preparing medicated drinking water, avoid direct contact with the eyes and skin. Wear a dust mask, coveralls and impervious gloves when mixing and handling this product. Eye protection is recommended. In case of accidental eye exposure, wash eyes immediately with water and seek medical attention. If wearing contact lenses, immediately rinse the eyes first, then remove contact lenses and continue to rinse the eyes thoroughly and seek medical attention. Avoid eating, chewing gum and smoking during handling. Wash contaminated skin. The Safety Data Sheet contains more detailed occupational safety information. To report adverse effects in users, to obtain more information or obtain a Safety Data Sheet, call Pharmgate Animal Health LLC. at 1-833-531-0114.

**PRECAUTIONS:** Not for use in lactating or pregnant females, or males and females intended for breeding. The effects of tylvalosin on swine reproductive performance, pregnancy, and lactation have not been determined. The safety and efficacy of this formulation in species other than swine have not been determined. To assure both food safety and responsible use in swine, concurrent use of tylvalosin in medicated drinking water and tylvalosin or another macrolide in medicated feed or by any other route of administration should be avoided. Tylvalosin belongs to the macrolide antimicrobial drug class. Macrolides are ranked as a critically important drug in human medicine; therefore, minimizing the risk of development of antimicrobial resistance to this class of drug is very important. The following conditions of use and restrictions listed below are critical for the FDA's strategy of risk management associated with tylvalosin: Always treat the fewest number of animals necessary to control a respiratory disease or PPE outbreak. Do not immediately follow this macrolide treatment with another macrolide treatment via any route.Prescriptions should not be renewed or refilled for animals already treated with one course of therapy with tylvalosin as directed (See Dosage and Administration above).

**ADVERSE REACTIONS IN ANIMALS:** No adverse reactions related to the drug were observed during clinical or target animal safety trials. To report suspected adverse reactions in animals, contact Pharmgate Animal Health LLC. at 1-833-531-0114. For additional information about adverse drug experience reporting for animal drugs, contact FDA at 1-888-FDA-VETS or at www.fda.gov/reportanimalae.

**CLINICAL PHARMACOLOGY:** Tylvalosin is a 16-membered semi-synthetic macrolide antibiotic. Macrolides are generally considered to be bacteriostatic agents that exert their antibiotic effect by reversibly binding to the 23S rRNA of the 50S ribosomal subunit, thereby inhibiting bacterial protein synthesis. The spectrum of activity of most available macrolides used in veterinary medicine is primarily against Gram-positive bacteria and Mycoplasmas, with some activity against Gram-negative fastidious bacteria. These compounds have no activity against the naturally resistant Enterobacteriaceae including *Escherichia coli* and *Salmonella* spp. Typically, macrolides achieve higher concentrations in tissues than in plasma.

**EFFECTIVENESS:**

**Control of Porcine Proliferative Enteropathy (PPE):** A multi-location challenge model study was conducted to confirm the effectiveness of Aivlosin® Water Soluble Granules for the control of PPE associated with *Lawsonia intracellularis*. Pigs were challenged by intragastric gavage with a mucosal homogenate containing a North American isolate of *Lawsonia intracellularis* isolated in 2005 that induces representative disease in challenged pigs. When at least 15% of the study pigs were showing signs of infection based on abnormal fecal scores, pigs were provided water containing tylvalosin at an inclusion rate of 50 ppm for five consecutive days, or were provided non-medicated water. Effectiveness was evaluated using clinical scores (pig demeanor score, abdominal appearance score, and fecal score) and clinically-validated gross PPE lesion scores. A conclusion of the effectiveness of 50 ppm tylvalosin for the control of PPE was determined based on a statistically significant ($p = 0.0103$) improvement in the clinically-validated gross PPE lesion scores in the 50 ppm tylvalosin-treated group compared to the non-medicated group.

**Control of Swine Respiratory Disease (SRD):** The effectiveness of Aivlosin® Water Soluble Granules for the control of swine respiratory disease (SRD) associated with *Bordetella bronchiseptica, Haemophilus parasuis, Pasteurella multocida, Streptococcus suis* and *Mycoplasma hyopneumoniae* was investigated in a natural field infection study conducted in the United States (three study sites) and Canada (one study site). Day 0 was defined when at least 15% of the candidate pigs were deemed clinically affected with SRD (moderate or severe respiratory score, moderate or severe depression score, and rectal temperature greater than or equal to 104.0 °F). On Day 0 a total of 980 pigs were enrolled and randomly assigned to a tylvalosin-treated group (50 ppm tylvalosin in drinking water for 5 consecutive days) or a non-medicated control group. Treatment success was evaluated on Day 7 and was defined as a pig with normal or mild respiratory score, normal or mild depression score, and rectal temperature less than 104.0 °F. The proportion of pigs meeting the definition of treatment success was numerically higher in the tylvalosin-treated group (48.5%) compared to the proportion of pigs meeting the definition of treatment success in the non-medicated control group (41.6%), and the observed difference was statistically significant ($p=0.0353$). Additional data to demonstrate the effectiveness of Aivlosin® Water Soluble Granules for the control of SRD associated with *Mycoplasma hyopneumoniae* was obtained in an experimentally-induced infection model study. Two hundred and forty (240) commercial crossbred pigs were challenged endotracheally with a representative isolate of *M. hyopneumoniae*. One hundred and ninety-two (192) study pigs were randomly assigned to either a tylvalosin-treated group (50 ppm tylvalosin in drinking water for 5 consecutive days) or a nonmedicated control group. Treatment was started when at least four of eight randomly pre-selected sentinel pigs exhibited a minimum of 3% weighted gross lung lesions consistent with *M. hyopneumoniae* infection. After a 5-day treatment period and a 5-day post-treatment period, study pigs were euthanized and necropsy performed to determine lung lesion scores. The analysis included 95 tylvalosin-treated pigs and 93 nonmedicated control pigs. There was a statistically significant ($P<0.0001$) improvement in pen mean *M. hyopneumoniae* lung lesion scores in the 50 ppm tylvalosin treated pigs (5.1%) compared to negative control (10.9%).

**ANIMAL SAFETY:**

Margin of safety: Aivlosin® Water Soluble Granules given orally in drinking water at 0, 50, 150 and 250 ppm tylvalosin (0, 1X, 3X and 5X the labeled dose, respectively) to 8 healthy pigs per treatment group over 15 days (3X the labeled duration) did not result in drug-induced clinical signs, gross pathologic lesions, histopathologic lesions or clinically-relevant clinical pathology abnormalities.

**STORAGE:** Store in a cool dry place at or below 25°C (77°F).

**HOW SUPPLIED:** Aivlosin® Water Soluble Granules is packaged in 160- and 400-gram sachets supplied in boxes holding 10 and 5 sachets respectively.

**LOT NO.:** Printed on label.

**EXPIRY:** Printed on label.

*Distributed in the USA by:*

**Pharmgate Animal Health LLC.**
14040 Industrial Road,
Omaha, NE 68144
www.pharmgateah.com

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**For technical assistance or to obtain a Safety Data Sheet, call Pharmgate Animal Health LLC. at 1-800-380-6099**

# Are you ready for that conversation?

We should all be proud of what we do for a living. We provide care to animals so we can supply healthy nutritious food for people around the world. It is a noble mission but unfortunately not everyone understands what we do. You never know when and where you will find yourself in a position to educate others about animal agriculture. Note that I did not say defend animal agriculture. If we continually do our best to provide care for the animals, use antibiotics judiciously, and protect the environment, we have nothing to defend. We simply need to educate.

Years ago, I boarded an airplane for a business trip. I sat down and greeted the lady in the seat beside me. We made the usual small talk; is your trip business or pleasure? I responded with business and the next logical question was "what do you do for a living?" After I explained that I was a veterinarian for a large pork production company, she giggled a little and informed me that she was a vegetarian and a member of People for the Ethical Treatment of Animals (PETA). She was watching me closely in eager anticipation of my reaction. I smiled and said, "well good, we have one thing in common. We both care deeply about animals." I am proud of our animal care program and anxious to share with anyone who will listen. That lady learned why we castrate baby pigs, dock tails, have hospital pens, provide gruel feed, pay close attention to the pig's environment, and how animal handling is performed. We had a nice conversation. I do not know if she is still a member of PETA today, but I do know that she was kind enough to listen and far better informed about how pork producers care for their animals by the time that flight ended.

The use of antibiotics in livestock is another topic that commonly arises. As veterinarians we should be well versed on the subject and always ready to educate others. I have a note card in my office desk drawer titled "Antibiotics" with these three bullet points: 1) The risk to humans is negligible. 2) Not treating leads to undue suffering and death. 3) Healthy animals make safe food. I believe this came from a presentation Dr Scott Hurd gave at an AASV Annual Meeting. Shame on me for not referencing the author or year, but obviously the message resonated with me. With those three bullet points you can add as little or as much detail as necessary to tell our story. I appreciate him sharing that simple approach.

A third topic that I think we will need to provide education on is agriculture's role in global warming. I suspect that like other businesses, animal agriculture will come under increased scrutiny as it relates to protecting the environment. That was why I wanted to introduce Dr Frank Mitloehner to our members and invited him to be a speaker at this years' AASV Annual Meeting. I wish I had a dime for every time I have heard global warming, the Green New Deal, or carbon footprint in the past couple of years. I will be honest, I am not well versed on the subject. I am not sure that we as veterinarians need be experts in this area, but it may prove beneficial to be equipped with a few tools to educate others if approached.

Agriculture accounts for less than 10% of all US greenhouse gas emissions with pork production producing less than 0.46%.[1] Manure is a renewable resource. It builds soil health and replaces the need for commercial fertilizer which would either be synthetic or mined. Dr Mitloehner taught us that livestock do indeed produce methane gas which goes into the environment, traps the sun's heat, and can cause elevated atmospheric temperatures. The good news is that methane gas breaks down in about 10 years and is recycled. Stable livestock herds do not add warmth to our climate and as we become more efficient, we require fewer inputs to produce more pork, so our global footprint has shrunk over the years rather than expanded. By covering lagoons, the gas produced by our animals can be captured and used for fuel. So, US livestock do not increase global warming, but are a net global cooler. Pork producers are helping solve the greenhouse gas problem. What a wonderful story to share!

*"You never know when and where you will find yourself in a position to educate others about animal agriculture."*

Join Operation Main Street to help prepare yourself for these conversations or take a moment to put together your own talking points. You can find great information in the We Care Sustainability Report Executive Summary, which can be accessed at **bit.ly/3dFORjW**. You never know when an opportunity to share our story will present itself.

Mary Battrell, DVM
*AASV President*

## Reference

*1. US Environmental Protection Agency. Inventory of US greenhouse gas emissions and sinks 1990-2016. EPA 430-R-18-003. April 2018. Accessed April 7, 2021. **https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf***

*Non-refereed reference.

# PROVEN IMPACT AGAINST *MYCOPLASMA HYOPNEUMONIAE*.[1]

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# How are the pigs today?

When I was in practice at Carroll's Foods back in the dark ages, the CEO would stop me in the hall at least once a week and ask, "How are the pigs today?" At that time, Carroll's had over 170,000 sows and their offspring spread across multiple states and two continents. There is no 30-second elevator answer for that question. These days, I am often asked about what the American Association of Swine Veterinarians (AASV) is doing to address the threat of African swine fever (ASF). It is a similarly hard question to answer, but it seems like it takes up about 75% of my workday.

As you might imagine, we work very closely with the National Pork Board (NPB), the National Pork Producers Council, and the Swine Health Information Center to address this issue. In addition, we also collaborate with federal and state animal health officials, researchers, and allied industry groups (eg, groups representing processing facilities and feed manufacturers). Outbreak prevention and response must be a collaborative effort between regulators and the industry. The ASF threat touches more than just swine health. Preventing, diagnosing, and responding to an outbreak also involve processing, feed manufacturing, feed ingredients, rendering, access to international markets, animal movements, consumer perceptions, and the list goes on.

Dr Liz Wagstrom recently put together a list of groups and projects we have been and continue to be involved in to address the ASF challenge. With her permission, I have modified and summarized that list below to highlight those activities in which AASV is actively involved. There are additional technical efforts going on to address specific pieces of the puzzle that do not directly involve AASV.

## US Department of Agriculture led groups

1. **Animal and Plant Health Inspection Service ASF Technical Working Group:**
   **Mission:** This 12-member working group serves as a resource for the Animal and Plant Health Inspection Service's (APHIS) ASF planning team to share their thinking and get feedback from members so we can identify what response strategies will work well and where APHIS may need to adapt.

2. **APHIS ASF Packer Technical Working Group:**
   **Mission:**
   - Identify gaps that will impact slaughter plant operations and define concept of operations for slaughter plant facilities in an ASF outbreak (in free areas and control zones). This includes utilizing the hot wash questions developed by industry following the recent packing plant policy workshop.
   - Operationalize solutions such as establish standards, draft guidance, create templates, and update the Red Book. Emphasis is placed on policy and operational solutions.
   - Determine roles and responsibilities between the state and federal government and slaughter and rendering facilities and identify gaps, solutions, and critical barriers.
   - Support and coordinate APHIS response to industry business continuity efforts:
     - Industry preparedness checklist based on state and federal government guidance.
     - Outline plant activities needed for implementation within the initial 72 hours post ASF detection in the United States.
   - Coordinate activities of the working group with workshops or exercises and translate lessons learned into policy where appropriate.
   - Help share education, outreach, and training resources both internally and externally.
   - Regularly update the APHIS ASF Technical Working Group to ensure continued coordination and collaboration.

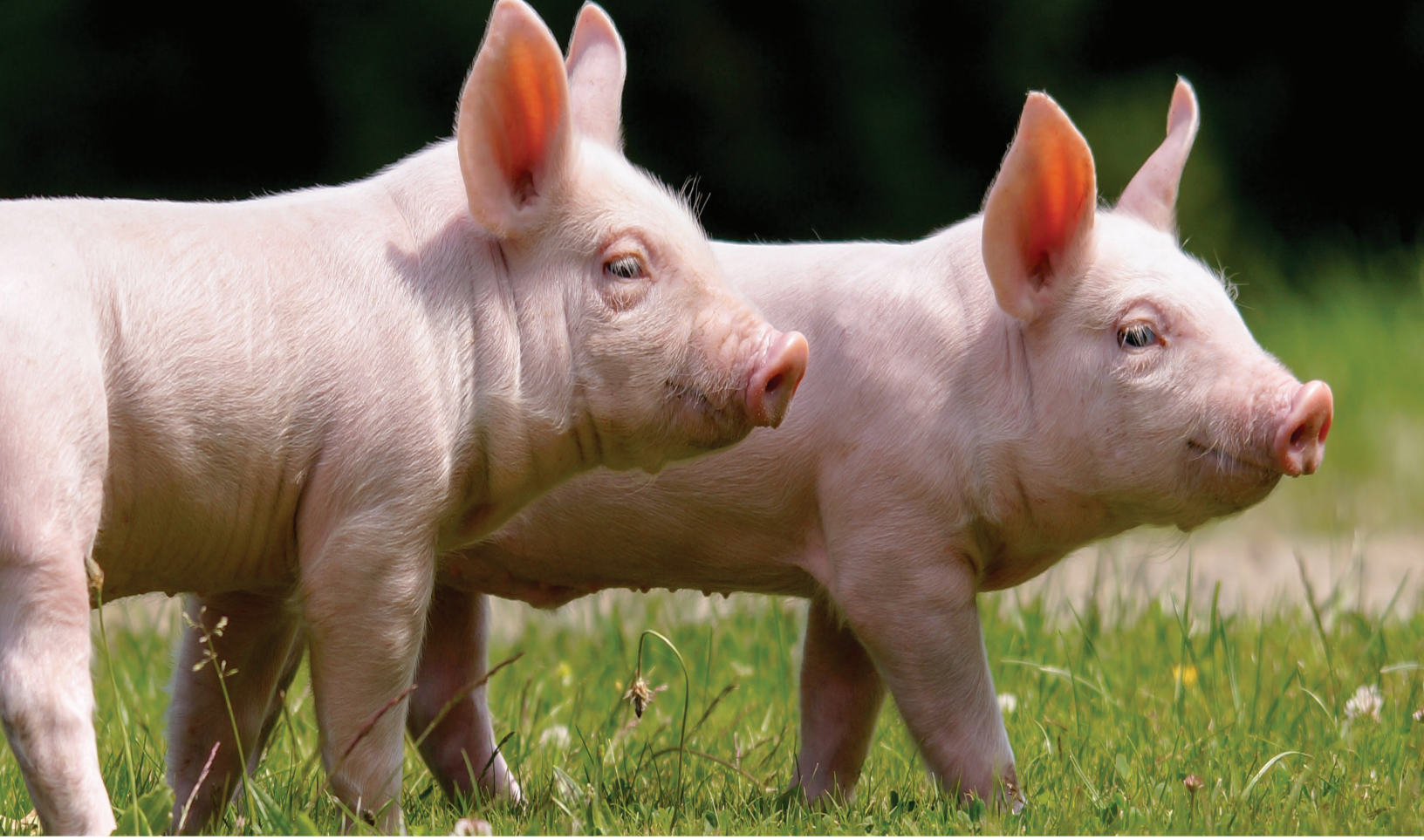
3. **North American Swine Health Working Group:**
   **Mission:** The group reports to the Chief Veterinary Officers of Canada, Mexico, and the United States. Participants share technical information on animal health programs and processes related to the prevention, preparedness, control, and recovery of disease incursions in domestic swine, and the risks of certain swine diseases such as ASF and classical swine fever (CSF).

## US Department of Agriculture funded projects

1. **Swine Health Improvement Plan pilot program**
   **Objective:** Develop and implement an ASF and CSF monitored certification program modelled after the basic tenets of the NPIP H5/H7 Avian Influenza Monitored Certification of the US commercial poultry industry.

2. **Swine depopulation resources**
   **Objective:** Funded by US Department of Agriculture's (USDA) National Animal Disease Preparedness and Response Program (NADPRP),

*Executive Director's message continued on page 177*



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*Executive Director's message continued from page 175*

this project aims to utilize the swine industry's recent experiences to provide further education and resources for swine veterinarians and farmers to build and improve capabilities and capacities for responding to future emergency events that require depopulation by:

- Conducting interviews with individuals who have depopulated swine to gather and compile data on setup, implementation, and efficacy of swine depopulation methods.
- Building from the survey results and American Veterinary Medical Association's depopulation guidelines, develop swine-specific recommendations for practical implementation of depopulation methods.
- Developing supplemental education resources, including depopulation method decision making tools, equipment lists, recordkeeping forms, and team debriefing tools, to assist swine veterinarians and farmers before and after the depopulation event occurs.

3. **Foreign Animal Disease Capacity Building**
   **Objectives:** Funded by a grant from USDA NADPRP, this project will develop, pilot, and implement two national training programs to help build personnel capacity and increase efficiency during a foreign animal disease (FAD) outbreak.
   - An on-farm immersion course that will provide hands-on training for FAD diagnosticians and other animal agriculture sector responders. Two pilot courses will be offered in summer and fall 2021.
   - Certified Swine Sample Collector training program will allow production field staff, producers, barn managers, and others that many swine-focused veterinarians already rely on for diagnostic sample collection to become an asset to assist in diagnostic sample collection and submission during an FAD response. The curriculum and resources will be used by category II accredited veterinarians for pig producers and pig industry personnel. Program standards and resources to be released by July for trainings to begin.

## State animal health organization led groups

1. **Fifteen-State Animal Health Official Group**
   **Mission:** Coordinate preparedness and response strategies between the top swine state animal health officials.

2. **US Animal Health Association Sampling and Testing group**
   **Mission:** Evaluate ASF surveillance plans (pre-outbreak for early detection, post outbreak in surveillance zones and free areas, and premovement during an outbreak). Determining the type, number, and timing of tests needed to move swine safely and confidently within and from a Control Area. Secondary objectives are to determine if those protocols could be applicable to CSF and foot-and-mouth disease and developing protocols to release an infected farm from quarantine.

## Packer Business Continuity Group

**Mission:** to develop a business continuity plan by which individual packers working with their suppliers could provide assurance of an ASF negative product to trading partners in the event of an ASF outbreak.

## Pork producer organization led groups

1. **NPB ASF Working Group**
   **Mission:** To review and act on strategic health issues, particularly ASF, which may affect the productivity of swine herds and global trade issues. To provide recommendations to the National Swine Disease Council to maintain and improve swine herd health. To identify, prioritize, review, and allocate Checkoff dollars for proposed research projects, determining outreach and educational priorities for producers, and establishing positions regarding ASF and other FADs to represent the best interest of the pork industry.

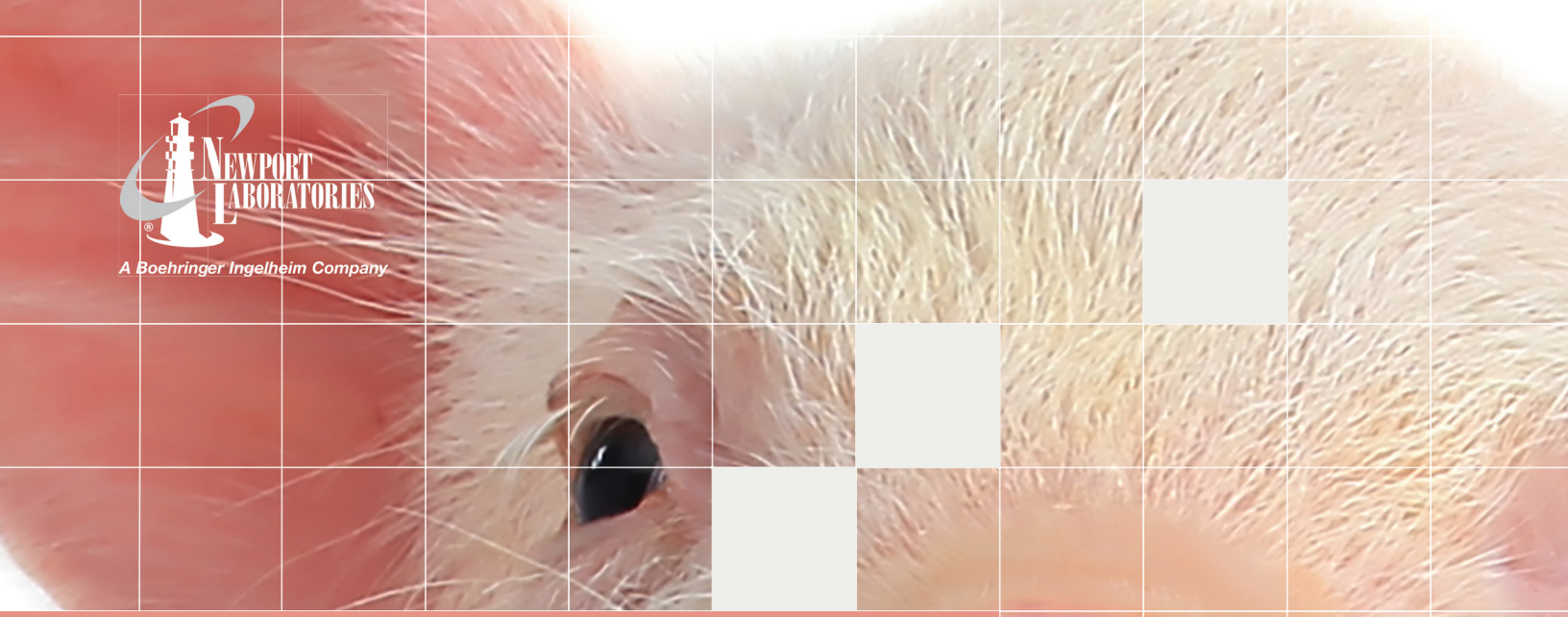
2. **National Swine Disease Council**
   **Mission:** To guide, develop and advocate for actions and policies for implementation across the pork chain to prevent, prepare for, and respond to threats to the US pork industry from diseases of concern.

3. **NPB Surveillance Working Group**
   **Mission:** To support disease surveillance efforts for the US pork industry by determining research priorities, providing input into training programs, and evaluating current surveillance efforts.

4. **Feed Risk Task Force**
   **Mission:** Evaluate the risk of introduction of pathogens into and within the United States via imported feed products and help decide what actions need to be taken to protect the US pork industry from that risk. Actions should be achievable, based on science, and minimize trade disruptions. The discussions will inform stakeholders about issues related to risk from feed and give participants the opportunity to identify existing scientific data gaps around various risk mitigation efforts.

I hope this highlights the fact that preventing and responding to a potential ASF outbreak is a multifaceted and collaborative effort. There is a lot going on behind the scenes. We are more prepared today than we ever have been, but we will never be fully prepared. As Dwight D. Eisenhower said, "Plans are worthless, but planning is everything." And, in case you are wondering, my response to the CEO who asked, "How are the pigs today?" was "Now is not the time to fire your veterinarian!"

**Harry Snelson, DVM**
*Executive Director*



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# Welcome

I am writing this message in the spring and at the end of the academic year for our veterinary students. And although this message will reach you mid-summer, I wanted to say congratulations to our new colleagues who have entered the profession. In fact, all students deserve a well-earned "well done!" for their determination and hard work navigating a challenging academic year.

As our student veterinarians graduate and enter the profession officially, many new, young students are accepted into DVM programs. As the summer progresses so will the news of students accepting offers of admissions across the world. As a profession, we are fortunate to attract such dedicated and high-quality students to the profession regardless of their interests or ultimate veterinary career path. I recognize that I am biased, but I wholeheartedly believe that our profession is the best!

Welcome to our new veterinary graduates and welcome to our new veterinary students.

I hope you enjoy this issue and have an enjoyable summer!

*"In fact, all students deserve a well-earned "well done!" for their determination and hard work navigating a challenging academic year."*

Terri O'Sullivan, DVM, PhD
*Executive Editor*

ORIGINAL RESEARCH PEER REVIEWED

# Field evaluation of a new single-dose *Mycoplasma hyopneumoniae* bacterin effects on growth performance

SooHwan Kim, DVM; Taehwan Oh, DVM; Siyeon Yang, DVM; Kee Hwan Park, DVM; Hyejean Cho, MS; Chanhee Chae, DVM, PhD

## Summary

**Objective:** Evaluate the efficacy of a new single-dose bacterin against *Mycoplasma hyopneumoniae* under field conditions.

**Materials and methods:** Three separate farms were selected based on their history of enzootic pneumonia. On each farm, vaccinated pigs (n = 20; 10 male and 10 female) were administered a single dose of the *M hyopneumoniae* bacterin at 21 days of age while unvaccinated pigs (n = 20; 10 male and 10 female) were administered a single dose of phosphate buffered saline at the same age.

**Results:** Vaccination against *M hyopneumoniae* reduces the severity of lung lesions and clinical signs such as coughing, which leads to improved growth performance of the pig. Vaccinated pigs had a significantly higher ($P = .02$ for farm A, $P = .02$ for farm B, and $P = .02$ for farm C) average daily weight gain between 21 to 175 days old (0 to 154 days post vaccination) and elicited cell-mediated immunity, as measured by *M hyopneumoniae*-specific interferon-γ secreting cells, when compared with unvaccinated pigs located at all 3 farms.

**Implications:** The data presented in this field study demonstrated that the *M hyopneumoniae* bacterin improved growth performance effectively in 3 farms suffering from enzootic pneumonia.

**Keywords:** swine, enzootic pneumonia, *Mycoplasma hyopneumoniae*, vaccine

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**Resumen - Evaluación de campo de los efectos de una nueva vacuna de dosis única de bacterina *Mycoplasma hyopneumoniae* sobre el rendimiento del crecimiento**

**Objetivo:** Evaluar la eficacia de una nueva bacterina de dosis única contra *Mycoplasma hyopneumoniae* en condiciones de campo.

**Materiales y métodos:** Se seleccionaron tres granjas diferentes en función de su historial de neumonía enzoótica. En cada granja, a los cerdos vacunados (n = 20; 10 machos y 10 hembras) se les administró una dosis única de la bacterina *M hyopneumoniae* a los 21 días de edad, mientras que a los cerdos no vacunados (n = 20; 10 machos y 10 hembras) se les administró una sola dosis de solución salina tamponada con fosfato a la misma edad.

**Resultados:** La vacunación contra *M hyopneumoniae* reduce la gravedad de las lesiones pulmonares y los signos clínicos como la tos, lo que mejora el crecimiento del cerdo. Los cerdos vacunados tuvieron un aumento de peso promedio diario significativamente mayor ($P = .02$ para la granja A, $P = .02$ para la granja B, y $P = .02$ para la granja C) entre los 21 y 175 días de edad (0 a 154 días después de la vacunación) y provocó inmunidad celular, medida por células secretoras de interferón-γ específicas de *M hyopneumoniae*, en comparación con cerdos no vacunados ubicados en las 3 granjas.

**Implicaciones:** Los datos presentados en este estudio de campo demostraron que la bacterina contra *M hyopneumoniae* mejoró el rendimiento del crecimiento de manera efectiva en 3 granjas que padecían neumonía enzoótica.

**Résumé - Évaluation terrain des effets sur les performances de croissance d'une nouvelle bactérine à dose unique contre *Mycoplasma hyopneumoniae***

**Objectif:** Évaluer l'efficacité d'une nouvelle bactérine à dose unique contre *M hyopneumoniae* dans des conditions de terrain.

**Matériels et méthodes:** Trois fermes distinctes ont été sélectionnées en fonction de leur histoire de pneumonie enzootique. Dans chaque ferme, des porcs vaccinés (n = 20; 10 mâles et 10 femelles) ont reçu une dose unique d'une bactérine contre *M hyopneumoniae* à 21 jours d'âge, tandis que des porcs non vaccinés du même âge (n = 20; 10 mâles et 10 femelles) ont reçu une dose unique de solution saline tamponnée.

**Résultats:** La vaccination contre *M hyopneumoniae* a réduit la sévérité des lésions pulmonaires et des signes cliniques tels que la toux, ce qui a entrainé

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une amélioration des performances de croissance des porcs. Les porcs vaccinés avaient un gain de poids quotidien moyen significativement plus élevé ($P = .02$ pour la ferme A, $P = .02$ pour la ferme B, et $P = .02$ pour la ferme C) entre 21 et 175 jours (0 à 154 jours après la vaccination) et suscité une immunité à médiation cellulaire, telle que mesurée par les cellules sécrétant l'interféron-γ spécifique de *M hyopneumoniae*, par rapport aux porcs non vaccinés situés dans les trois fermes.

**Implications:** Les données présentées dans cette étude de terrain ont démontré que la bactérine contre *M hyopneumoniae* améliorait efficacement les performances de croissance des animaux dans trois fermes au prise avec la pneumonie enzootique.

*Mycoplasma hyopneumoniae* can be an important pathogen in porcine respiratory disease complex[1] as well as the primary pathogen of enzootic pneumonia, a chronic respiratory disease in growing pigs resulting from combined infections of *M hyopneumoniae* and one or more secondary bacterial pathogens.[2] Enzootic pneumonia is characterized by a persistent nonproductive cough with a reduced growth rate, a poor feed conversion ratio, high morbidity, and low mortality.[3,4] The economic impact of *M hyopneumoniae* infections in swine farms worldwide can be considered significant.

Several strategies may be implemented to successfully prevent and control *M hyopneumoniae* including optimized management practices and vaccination.[5] While all-in/all-out production and multisite operations are great management tools, vaccination remains an important and cost-effective method for reducing the impact of *M hyopneumoniae* infection. The *M hyopneumoniae*-free status of herds is difficult to maintain especially in pig-dense areas, since the airborne spread of this pathogen may occur over several kilometers.[6]

In Korea, approximately 70% of total piglets farrowed in 2018 were vaccinated with *M hyopneumoniae* (**http://www.kahpha.or.kr**). Therefore, vaccination is one of the tools used to control *M hyopneumoniae*. The objective of this study was to evaluate the efficacy of a new single-dose *M hyopneumoniae* whole-cell bacterin (Hyogen, CEVA Santé Animale) based on strain BA 2940–99, oil adjuvanted with paraffin and *Escherichia coli* J5 LPS with thiomersal as excipient under field conditions in accordance with the registration guidelines of the Republic of Korea's Animal, Plant and Fisheries Quarantine and Inspection Agency (**http://www.qia.go.kr**).

## Materials and methods

The protocol for this field study was approved by the Seoul National University Institutional Animal Care and Use Committee (approval number SNU-180621-13).

### Farm histories

The clinical field trial was conducted on 3 Korean swine farms (denoted as Farms A, B, and C) between August 2018 and February 2019. Status of porcine reproductive and respiratory syndrome (PRRS) was stable with no active PRRS virus circulation (high-parity sows were the only seropositive animals in the herd). Porcine circovirus type 2 (PCV2) was circulating in the postweaning and growing period without overt clinical signs of porcine circovirus-associated disease on the 3 farms.

Farm A was a conventional 400-sow farrow-to-finish swine farm where the owner complained about a dry recurrent cough beginning at 40 days of age accompanied by growth retardation. Real-time polymerase chain reaction (PCR) testing[7] of pneumonic and atelectatic lung samples from pigs at 49 days of age was conducted for *M hyopneumoniae* at the Veterinary Diagnostic Center, College of Veterinary Medicine, Seoul National University in May 2018. The testing returned positive results for 5 of the 7 lung samples submitted for *M hyopneumoniae*. The combined occurrence of clinical signs, detection of *M hyopneumoniae* by PCR, and histopathological lesions (peribronchiolar and perivascular lymphoid tissue hyperplasia) were indicative of an ongoing infection with *M hyopneumoniae*.

Farm B consisted of a conventional 150-sow farrow-to-finish swine farm managed in a 2-week batch system and included a history of enzootic pneumonia. Infection with *M hyopneumoniae* was evident by severe dry coughing, histopathological peribronchiolar lymphoid tissue hyperplasia, and detection of *M hyopneumoniae* in lung samples by real-time PCR[7] in all three of the 38-day-old pigs tested.

Farm C, a conventional 450-sow farrow-to-finish swine farm, was suggested to our clinical study team by its practitioner to participate in this field trial on *M hyopneumoniae* vaccine efficacy. A pilot survey was implemented to assess the circulation of *M hyopneumoniae* within the herd, as the producers had complained of severe dry coughing and retardation of growth between 10 and 50 days of age. Lung samples from 74-day-old pigs were submitted to the Veterinary Diagnostic Center, College of Veterinary Medicine, Seoul National University in June 2018. Three of the 5 lung sample submissions were positive for *M hyopneumoniae* using real-time PCR testing.[7] The histological lesions were characterized by peribronchiolar lymphoid tissues hyperplasia and bronchopneumonia. *Pasteurella multocida* was isolated in 4 of the 5 lung samples. These results were indicative of enzootic pneumoniae by *M hyopneumoniae* with secondary *P multocida* infection.

### Study design

The experimental design of the field study strictly adhered to the registration guidelines set by the Republic of Korea's Animal, Plant and Fisheries Quarantine and Inspection Agency. Guidelines require that 20 piglets (10 male and 10 female) be selected and assigned to each group of vaccinated and unvaccinated animals. To minimize sow variation, four to six 7-day-old piglets were randomly selected from each sow and assigned to either the vaccinated or unvaccinated group using the random number generator function in Excel (Microsoft Corporation). The pigs in the vaccinated groups were injected intramuscularly in the right side of the neck with 2 mL of the *M hyopneumoniae* bacterin (Hyogen, CEVA Santé Animale, Lot No.1405582B) at 21 days of age, while an equal volume of phosphate buffered saline (0.01M, pH 7.4) was injected in the same anatomical location for pigs of the unvaccinated groups. At 24 days of age, all vaccinated and unvaccinated pigs were transferred to the nursery facility and kept in co-mingled groups until the end of the trial. In the nursery, pigs were then randomly distributed into 4 total pens to include 10 pigs/pen, all within one room. A similar proportion of each treatment was included in each pen. All pens were identical in design and equipment which included free access to a feed and water trough in accordance with standard farm procedures. The 3 farms did not use feed or water medication effective against *M hyopneumoniae*. Antibiotics (ie, penicillin) were given to vaccinated and unvaccinated pigs to help control respiratory

diseases during the course of the study. Blood and nasal swabs were collected at study days 0 (21 days of age), 21 (42 days of age), 49 (70 days of age), 77 (98 days of age), and 105 (126 days of age).

## Mortalities

Pigs that died were subjected to gross pathological examination within 24 hours at a local veterinary practitioner's clinic. All major organs such as brain, lung, subinguinal lymph node, small and large intestine, liver, kidney, and tonsils were collected from each pig. In the case of lung lesions, samples were collected from the edge of these lesions. Polymerase chain reaction assays were used to detect specific nucleic acids for PCV2, PRRS virus, swine influenza virus, and *M hyopneumoniae*.[8-11] All other bacterial isolation and identifications were carried out by using routine methods.

## Clinical observations

Pig physical condition was monitored daily, and pigs were scored weekly for clinical respiratory disease from study days 0 to 105. Scores ranged from 0 to 6: 0 = normal; 1 = mild dyspnea, tachypnea, or both when stressed; 2 = mild dyspnea, tachypnea, or both when at rest; 3 = moderate dyspnea, tachypnea, or both when stressed; 4 = moderate dyspnea, tachypnea, or both when at rest; 5 = severe dyspnea, tachypnea, or both when stressed; 6 = severe dyspnea, tachypnea, or both when at rest. Observers were blinded to vaccination status.

## Growth performance

Pigs were weighed at study days 0 (21 days of age), 49 (70 days of age), 91 (112 days of age), and 154 (175 days of age). Average daily gain (ADG) was determined for study days 0 to 49, study days 50 to 91, and study days 92 to 154 (Table 1). The ADG during these various stages was calculated as the difference between the starting and final weight divided by the duration of the stage. Data for dead or removed pigs were included in the calculation.

## Quantification of *M hyopneumoniae* DNA in nasal swabs

Sterile polyester swabs (Fisher Scientific Inc) were used to swab the nasal mucosa of both nostrils, reaching deeply into the turbinates. Swabs were stored in 5 mL plastic tubes (Fisher Scientific Inc) containing 1 mL of sterile saline solution. A commercial kit (QIAamp DNA Mini Kit, QIAGEN) was used to extract DNA from nasal swabs to quantify the *M hyopneumoniae* genomic DNA copy numbers by real-time PCR as previously described.[7] To construct a standard curve, real-time PCR was performed in quadruplicate in 10-fold serial dilution of chromosomal DNA from *M hyopneumoniae* strain SNU98703, with concentrations ranging from 10 ng/µL to 1 fg/µL. One femtogram of chromosomal DNA from *M hyopneumoniae* is considered to be approximately one genome equivalent.[12] A negative control was included in each run using double distilled water as the template.

## Enzyme-linked immunosorbent assay

Blood samples were collected from each pig by jugular venipuncture. Serum samples were tested for *M hyopneumoniae* antibodies using a commercial enzyme-linked immunosorbent assay (ELISA; IDEXX Laboratories Inc). Serum samples were considered positive for *M hyopneumoniae* antibodies if the sample-to-positive (S:P) ratio was ≥ 0.4 in accordance with the manufacturer's instructions.

## Enzyme-linked immunospot assay

Blood samples were collected from each pig by jugular venipuncture. The enzyme-linked immunospot (ELISpot) assay was conducted to measure the number of *M hyopneumoniae*-specific interferon-γ secreting cells (IFN-γ-SC) in peripheral blood mononuclear cells (PBMC).[13] *Mycoplasma hyopneumoniae* antigens were prepared as previously described.[14] The IFN-γ positive spots on the membranes (MABTECH) were imaged, analyzed, and counted using an automated ELISPOT Reader (AID ELISPOT Reader, AID GmbH). The results were expressed as the number of IFN-γ-SC per million PBMC. The ELISpot assay was completed in duplicate.

## Pathological evaluation

Lung samples were collected in pigs from each group at study day 147 (168 days of age). Lung pathology evaluation was done by two pathologists (authors

**Table 1:** Mean (SD) average daily gain (ADG) in pigs vaccinated for *Mycoplasma hyopneumoniae* or unvaccinated pigs on 3 Korean swine farms*

| Farm | Group (n) | ADG (SD), g/day | | | |
|---|---|---|---|---|---|
| | | D 0-49 | D 50-91 | D 92-154 | D 0-154 |
| A | VacA (20) | 402 (19)[a] | 745 (30) | 763 (21) | 643 (10)[a] |
| | UnVacA (20) | 382 (22)[b] | 739 (39) | 743 (61) | 627 (25)[b] |
| B | VacB (20) | 390 (27)[a] | 755 (44) | 764 (40) | 643 (13)[a] |
| | UnVacB (20) | 367 (24)[b] | 739 (53) | 755 (40) | 627 (22)[b] |
| C | VacC (20) | 387 (28)[a] | 727 (26)[a] | 765 (28) | 634 (11)[a] |
| | UnVacC (20) | 366 (26)[b] | 704 (34)[b] | 760 (44) | 620 (22)[b] |

* The clinical field trial was conducted on 3 farms (A, B, and C). To minimize sow variation, four to six 7-day-old piglets were randomly selected from each sow and assigned to either the vaccinated or unvaccinated group using the random number generator function in Excel (Microsoft Corporation). Groups VacA, VacB, and VacC were vaccinated with a one-dose *M hyopneumoniae* bacterin (Hyogen, CEVA Santé Animale) at study day 0 (21 days of age). Groups UnVacA, UnVacB, and UnVacC were injected with phosphate buffered saline at study day 0 (21 days of age).

[ab] Within a column, values with different superscript letters are significantly different within each farm. ADG was compared between the two groups within each farm using a Student *t* test.

Oh and Chae) at the Seoul National University (Seoul, Republic of Korea). Macroscopic lesion scores were estimated, and a score was given to reflect the amount of pneumonia in each lobe. For the entire lung, up to 100 points were assigned as follows: 10 points each to the right cranial lobe, right middle lobe, left cranial lobe, and left middle lobe; 27.5 points each to the right caudal lobe and left caudal lobe; and 5 points to the accessory lobe.[15] Eight pieces of lung tissues (two pieces from the right cranial lobe, two from the right middle lobe, one from the ventromedial part of the right caudal lobe, one from the dorsomedial part of the right caudal lobe, one from the midlateral part of the right caudal lobe, and one from the accessory lobe) were collected from each pig. Three tissue sections of the eight lung pieces were examined blindly by two veterinary pathologists (Oh and Chae). Lung sections were scored for presence and severity of type 2 pneumocyte hypertrophy and hyperplasia, alveolar septal infiltration with inflammatory cells, peribronchial lymphoid hyperplasia, amount of alveolar exudate, and amount of inflammation in the lamina propria of bronchi and bronchioles ranging from 0 to 6: 0 = normal; 1 = mild multifocal; 2 = mild diffuse; 3 = moderate multifocal; 4 = moderate diffuse; 5 = severe multifocal; 6 = severe diffuse.[16]

### Statistical analysis

Prior to statistical analysis, real-time PCR data were transformed to $\log_{10}$ values to reduce variance and positive skewness. The normality of the distribution of the examined variables was evaluated by the Shapiro-Wilk test. Continuous data (ADG, real-time PCR, ELISA, and ELISpot) were analyzed with a Student *t* test to determine the significance of group differences at each time point. Discrete data (clinical signs and pathology lesions) were analyzed by Mann-Whitney test to determine the significance of group differences at each time point. A *P* value < .05 was considered significant.

## Results

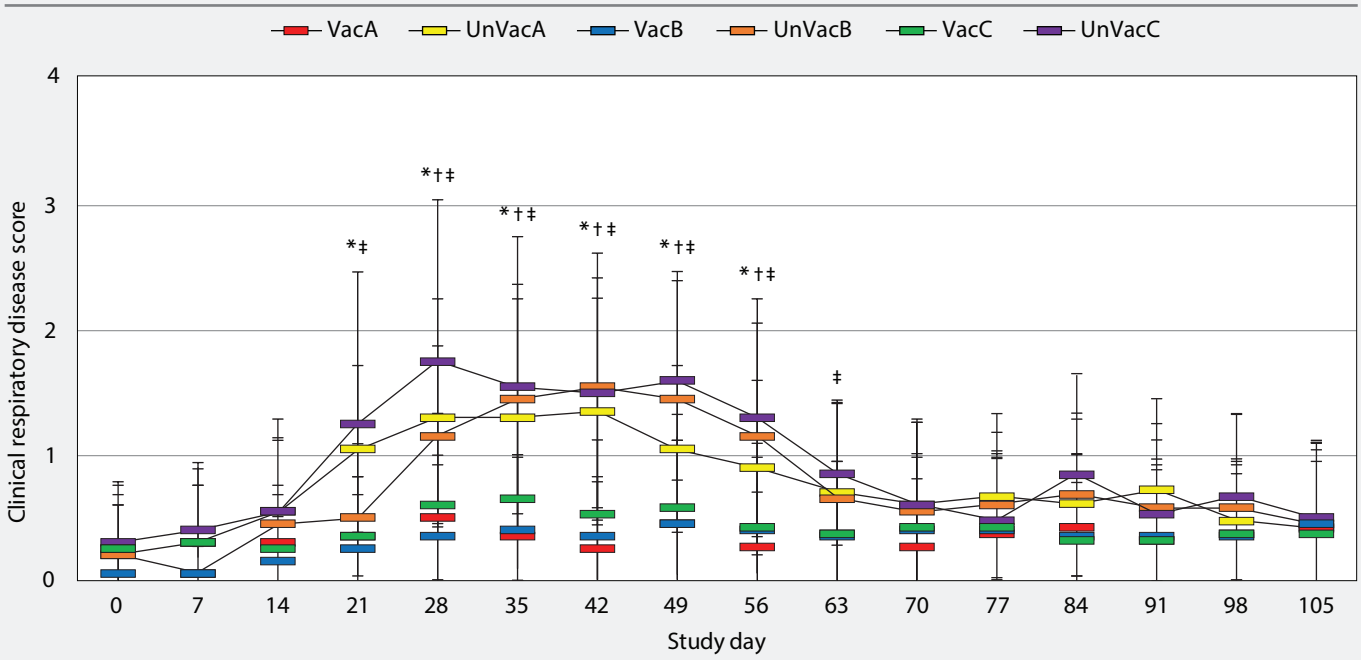
### Mortality

One vaccinated pig from farm A died of bronchopneumonia resulting from a combination of PCV2 that was detected with PCR and *Glasserella parasuis* that was isolated from the lung at study day 51 (72 days of age). Three unvaccinated pigs from farm A died of pleuropneumonia caused by a combination of *Actinobacillus pleuropneumoniae* and other bacteria. *Actinobacillus pleuropneumoniae* and *P multocida* were isolated from lung tissue at study days 74 (95 days of age) and 77 (98 days of age), and *A pleuropneumoniae* and *Streptococcus suis* were isolated from lung tissue at study day 93 (114 days of age). Farm C had 1 vaccinated pig die of salmonellosis at study day 42 (63 days of age) and 2 unvaccinated pigs died of bronchopneumonia caused by a combination of PCV2 that was detected with PCR and *P multocida* that was isolated from lung tissue at study day 72 (93 days of age) and 92 (113 days of age), respectively. But PCV2-associated lesions were not observed in lymph nodes from these 2 pigs.

### Clinical signs

Vaccinated pigs from farm A had significantly lower (*P* = .004) clinical respiratory scores when compared with unvaccinated pigs at study days 21 to 56. Farm B vaccinates also had significantly lower (*P* < .001) clinical respiratory scores when compared with unvaccinated pigs, but at study days 28 to 56. On farm C, vaccinated pigs had significantly lower (*P* = .002) clinical respiratory scores when compared with unvaccinated pigs at study days 21 to 63 (Figure 1).

**Figure 1:** Mean (SD) clinical respiratory disease scores of *Mycoplasma hyopneumoniae* vaccinated (Vac) or unvaccinated (UnVac) pigs on 3 Korean swine farms (A, B, and C). The study design is described in Table 1. Mean respiratory scores were scored on a scale from 0 to 6: 0 = normal; 1 = mild dyspnea, tachypnea, or both when stressed; 2 = mild dyspnea, tachypnea, or both when at rest; 3 = moderate dyspnea, tachypnea, or both when stressed; 4 = mild dyspnea, tachypnea, or both when at rest; 5 = severe dyspnea, tachypnea, or both when stressed; and 6 = severe dyspnea, tachypnea, or both when at rest. Significant difference (*P* value < .05; Mann-Whitney test) is indicated between vaccinated and unvaccinated groups within each farm (*farm A, †farm B, and ‡farm C).



### Growth performance

The body weight of pigs at study day 0 (21 days of age, time of vaccination) did not differ significantly between the vaccinated and unvaccinated groups on all 3 farms. Vaccinated pigs from all farms (A-C) had significantly higher ($P = .007$ for farm A, $P = .01$ for farm B, and $P = .03$ for farm C) ADG at study days 0 to 49 (21-70 days old) when compared with unvaccinated pigs from the same farm. Additionally, farm C vaccinated pigs had a significantly higher ($P = .031$) ADG at study days 50 to 91 (71-112 days old) when compared with the unvaccinated pigs. Overall (study days 0-154), the difference between vaccinated and unvaccinated groups was significant ($P = .02$ for farm A, $P = .02$ for farm B, and $P = .02$ for farm C) on all 3 farms (Table 1).

### Quantification of *M hyopneumoniae* in nasal swabs

On farm A, vaccinated pigs had a significantly lower ($P = .009$) number of genomic copies of *M hyopneumoniae* in their nasal swabs when compared with unvaccinated pigs at study day 21. On farm B, there was a numerical, but not statistically significant ($P = .05$), difference in the number of *M hyopneumoniae* genomic copies on the nasal swabs of vaccinated and unvaccinated pigs. Farm C vaccinated pigs had a significantly lower ($P = .02$ at study day 21, $P = .03$ at study day 49, and $P = .001$ at study day 77) number of *M hyopneumoniae* genomic copies in their nasal swabs when compared with unvaccinated pigs at study days 21, 49, and 77 (Figure 2).

### Serology

On farm A, vaccinated pigs had a significantly higher *M hyopneumoniae* ELISA S:P ratio at study days 49 ($P = .001$) and 77 ($P = .006$) when compared with unvaccinated pigs. On farm B, vaccinated pigs had a significantly higher ($P = .001$) *M hyopneumoniae* ELISA S:P ratio at study days 21, 49, and 77 when compared with unvaccinated pigs. On farm C, vaccinated pigs had a significantly higher ($P = .001$) *M hyopneumoniae* ELISA S:P ratio at study days 49 and 77 when compared with unvaccinated pigs (Figure 3).

### ELISpot

On farm A, vaccinated pigs had a significantly higher ($P < .001$) number of *M hyopneumoniae*-specific IFN-γ-SC at study day 49 in their PBMC when compared with the unvaccinated pigs. On farm B, vaccinated pigs had a significantly higher number of *M hyopneumoniae*-specific IFN-γ-SC in their PBMC at study days 21 ($P = .01$) and 49 ($P = .001$) when compared with the unvaccinated pigs. On farm C, vaccinated pigs had a significantly higher ($P = .002$) number of *M hyopneumoniae*-specific IFN-γ-SC at study days 49 and 77 in their PBMC when compared with the unvaccinated pigs (Figure 4).

### Pathology

Vaccinated pigs had significantly lower ($P < .001$) macroscopic and microscopic lung lesion scores when compared with the unvaccinated pigs on the 3 farms at study day 154 (Table 2).

## Discussion

In the present field trial, vaccination against *M hyopneumoniae* reduced the severity of lung lesions and clinical signs, including coughing, which resulted in improved growth performance. Controlling *M hyopneumoniae* and its associated diseases in the field can be challenging. Vaccination against *M hyopneumoniae* using commercial vaccines is the most common strategy within Asian swine production systems. The major advantages of vaccination include reduction of clinical signs and pneumonic lung lesions and improvement of daily weight gain in field trials.[17-20] No statistically significant difference was observed in the growth performance (ADG) over the nursery period between groups. This confirmed that vaccine did not have a detectable negative impact on growth performance shortly after injection. Overall (study days 0 to 154), the difference in growth performance between vaccinated and unvaccinated pigs was significant on all 3 farms where *M hyopneumoniae* was circulating.

**Figure 2:** Mean (SD) number of *Mycoplasma hyopneumoniae* (Mhp) genomic copies in nasal swabs from vaccinated (Vac) and unvaccinated (UnVac) pigs on 3 Korean swine farms (A, B, and C). The study design is described in Table 1. Significant difference (*P* value < .05; Student *t* test) is indicated between vaccinated and unvaccinated groups within each farm (*farm A and ‡farm C).

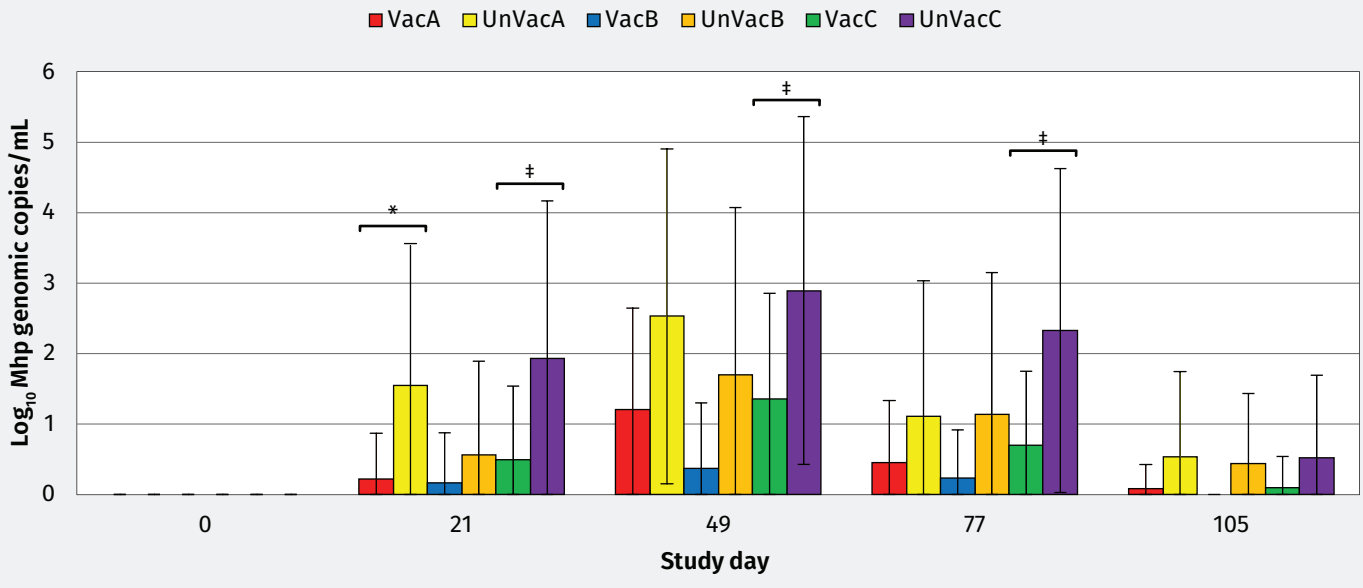


**Figure 3:** Mean (SD) sample-to-positive (S:P) ratio in serum samples from *Mycoplasma hyopneumoniae* (Mhp) vaccinated (Vac) and unvaccinated (UnVac) pigs on 3 Korean swine farms (A, B, and C). The study design is described in Table 1. Significant difference (*P* value < .05; Student *t* test) is indicated between vaccinated and unvaccinated groups within each farm (*farm A,†farm B, and ‡farm C).

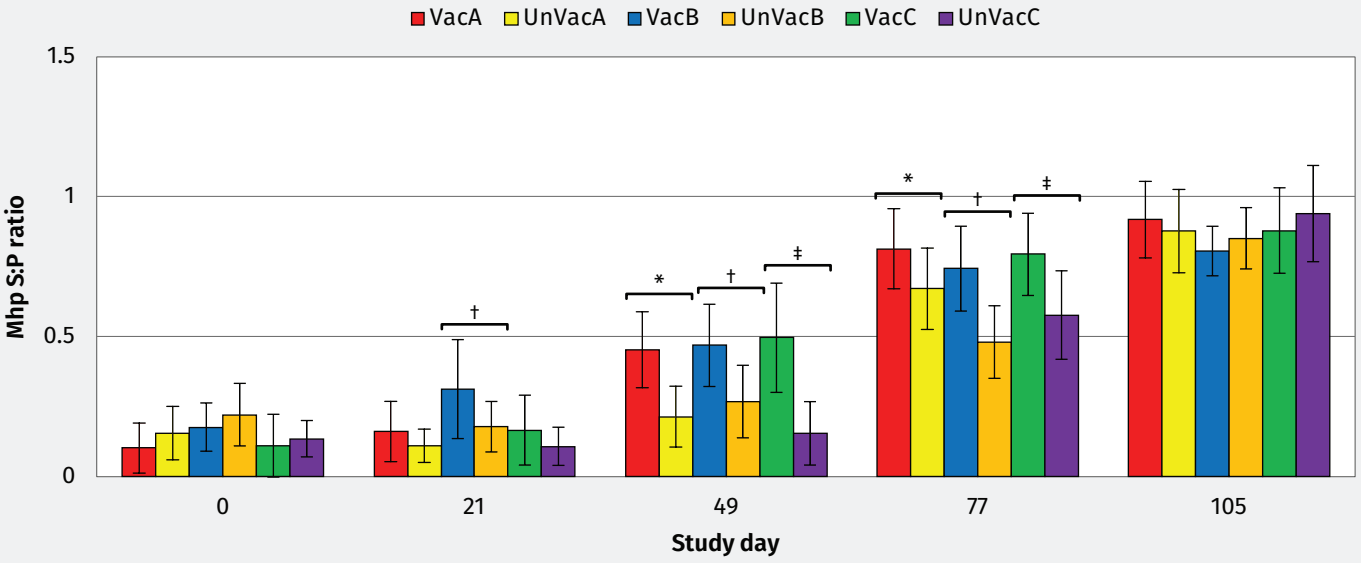



**Figure 4:** Mean (SD) *Mycoplasma hyopneumoniae* (Mhp)-specific interferon-γ secreting cells (IFN-γ-SC) in peripheral blood mononuclear cells (PBMC) in vaccinated (Vac) and unvaccinated (UnVac) pigs on 3 Korean swine farms (A, B, and C). The study design is described in Table 1. Significant difference (*P* value < .05; Student *t* test) is indicated between vaccinated and unvaccinated groups within each farm (*farm A, †farm B, and ‡farm C).

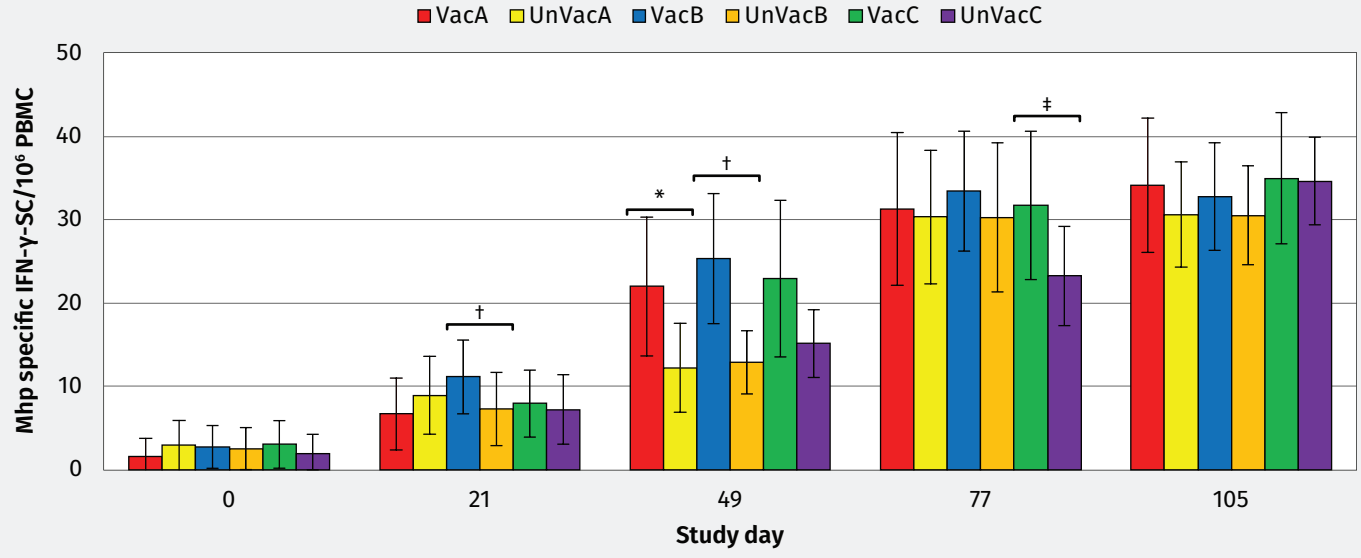


**Table 2:** Mean (SD) lung lesion scores*

| Farm | Group (n) | Macroscopic lesion scores | Microscopic lesion scores |
|---|---|---|---|
| A | VacA (20) | 12 (13.57)[a] | 0.7 (0.32)[a] |
| | UnVacA (20) | 50 (15.05)[b] | 1.7 (0.36)[b] |
| B | VacB (20) | 14 (11.48)[a] | 0.9 (0.32)[a] |
| | UnVacB (20) | 46 (21.10)[b] | 1.7 (0.38)[b] |
| C | VacC (20) | 14 (12.51)[a] | 0.6 (0.27)[a] |
| | UnVacC (20) | 46 (25.51)[b] | 1.9 (0.41)[b] |

* Study design described in Table 1.

[ab] Within a column, values with different superscript letters are significantly different within each farm. Macroscopic and microscopic lesion scores were compared between the two groups within each farm using a Mann-Whitney test.

The mycoplasma organism is a small bacterium without a cell wall. It is a unique pathogen in that it does not invade the body, but instead colonizes the mucosal surface of the respiratory tract damaging the cilia.[21,22] Therefore, the serum antibody response to the bacteria may be variable and not a great measurement of protective immunity. No correlation between vaccine-induced serum antibody levels and protection from colonization and disease has been determined.[13,23] Although protective immunity against *M hyopneumoniae* is not fully understood, cell-mediated immunity is likely to play an important role in the protection against *M hyopneumoniae* infection as described in previous studies.[13,23] In this study, *M hyopneumoniae*-specific IFN-γ-SC gradually increased from day 21 and reached a peak at day 49. During this period, vaccinated groups improved ADG and reduced respiratory signs significantly compared with unvaccinated groups on the 3 farms. These results indicate that *M hyopneumoniae*-specific IFN-γ-SC may provide protective immunity. However, since increased levels of IFN-γ-SC coincide with the increased amount of mycoplasmal loads in nasal shedding, further studies are needed to determine the functional role of cell-mediated immunity as a protective immunity.

The clinical impact of reducing nasal mycoplasmal shedding by vaccine may be controversial. The vaccine used in this study reduced the genomic copies of *M hyopneumoniae* on the nasal swabs from vaccinated pigs. Similarly, some studies indicate that other commercial vaccines may also reduce the number of organisms in the respiratory tract and may decrease the infection level in a herd.[24] Contradictory to these findings, additional field studies have shown that vaccination does not significantly reduce the transmission of this respiratory pathogen.[25] In addition, vaccines do not prevent colonization.[17-19,26] Consequently, vaccination alone will not be sufficient to eliminate *M hyopneumoniae* from infected pig herds. The producer must still pay attention to stocking density, ventilation, biosecurity, and the control of other diseases to be successful in the long-term control of mycoplasma.

Different sampling sites were used to detect *M hyopneumoniae* infection by PCR on experimentally and naturally infected pigs. Laryngeal swabs were a reliable sample for early detection of *M hyopneumoniae*, followed by broncho-alveolar lavage fluid and nasal swabs in live experimentally infected pigs, especially during the acute period.[27] In contrast, the most sensitive sampling sites in live naturally infected pigs were tracheo-bronchial swabbing and tracheo-bronchial washing, as compared to oral-pharyngeal brushing and nasal swabbing.[28] This may partly explain the relative inaccuracy of the nasal swabbing method.[28] In the present study, sterile swabs were inserted into nasal turbinates deeply and rotated hard enough on the inside of the nose to collect the samples properly for the detection of *M hyopneumoniae*. In addition, nasal swabs are practical samples for the detection of *M hyopneumoniae* under field conditions.

*Mycoplasma hyopneumoniae* is a slow-growing bacterial organism with a long period between infection and clinical impact.[29] Early infection during the life of a pig is important for the organism to grow and develop clinical disease in pigs. *Mycoplasma hyopneumoniae* prevalence at weaning can be an important indicator of disease severity in growing pigs.[30] Thus, control measures directed at lowering *M hyopneumoniae* prevalence at weaning could have a significant impact in disease presentation in grow-finishing pigs. This enhances the criticality that early control of *M hyopneumoniae* infection by vaccination is essential to control mycoplasma pneumonia. Early vaccination of piglets (< 3 weeks of age) is more common in single-site herds in Korea. Early vaccination has the advantage that immunity can be induced before the pigs become infected, and that fewer pathogens are present to possibly interfere with an immune response. In this field trial, commercial *M hyopneumoniae* vaccine was also administered to piglets at 3 weeks of age as recommended by company claims.

Single-dose *M hyopneumoniae* vaccination at 3 weeks of age significantly improved growth performance in pig farms suffering from *M hyopneumoniae* infection. This field trial was conducted on 3 farms and included housing conditions and a health status reflecting those of conventional facilities in Korea. The results of this study demonstrate that the newly introduced *M hyopneumoniae* vaccine provided good protection against *M hyopneumoniae* on farms.

## Implications

Under the field conditions of this study:

- *Mycoplasma hyopneumoniae* bacterin effectively improved growth performance.
- *Mycoplasma hyopneumoniae* bacterin reduced pathological lung lesions.

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### Conflict of interest

None reported.

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*Non-refereed reference.

# Conversion tables

## Weights and measures conversions

| Common (US) | Metric | To convert | Multiply by |
|---|---|---|---|
| 1 oz | 28.35 g | oz to g | 28.35 |
| 1 lb (16 oz) | 0.45 kg | 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) | 0.3 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 $ft^3$ | 35.3 |
| 1 gal (128 fl oz) | 3.8 L | gal to L | 3.8 |
| 0.26 gal | 1 L | L to gal | 0.26 |
| 1 qt (32 fl oz) | 0.95 L | qt to L | 0.95 |
| 1.06 qt | 1 L | L to qt | 1.06 |

## Temperature equivalents (approx)

| °F | °C |
|---|---|
| 32 | 0 |
| 50 | 10.0 |
| 60 | 15.5 |
| 61 | 16.1 |
| 65 | 18.3 |
| 70 | 21.1 |
| 75 | 23.8 |
| 80 | 26.6 |
| 82 | 27.7 |
| 85 | 29.4 |
| 90 | 32.2 |
| 102 | 38.8 |
| 103 | 39.4 |
| 104 | 40.0 |
| 105 | 40.5 |
| 106 | 41.1 |
| 212 | 100.0 |

°F = (°C × 9/5) + 32

°C = (°F - 32) × 5/9

Conversion calculator available at: amamanualofstyle.com/page/si-conversion-calculator

## 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 | 136 |
| | 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

PEER REVIEWED ORIGINAL RESEARCH

# Effects of iron dosage administered to newborn piglets on hematological measures, preweaning and postweaning growth performance, and postweaning tissue mineral content

Tyler B. Chevalier, MS; H. James Monegue, MS; Merlin D. Lindemann, PhD

## Summary

**Objective:** To evaluate the effect of iron dosage given at birth on pig growth performance, the course of the preweaning and postweaning blood profile, and postweaning tissue mineral concentration.

**Materials and methods:** Crossbred pigs (n = 70) were assigned to 1 of 5 iron dosages (0, 50, 100, 200, and 300 mg iron) administered by injection on day 0. Body weight and blood samples were collected at day 0, 1, 2, 3, 4, 6, 8, 11, 17, 22, 23, 24, 25, 29, 38, and 52. All blood samples were analyzed for complete blood count (CBC) profile. On day 22, 38, and 52, tissues from 3 pigs per treatment were obtained for analysis of trace minerals (Fe, Zn, Cu, and Mn).

**Results:** Pigs receiving no iron at birth had the slowest growth and lowest hematological profile demonstrating that iron deficiency anemia (IDA) was induced. Hemoglobin concentrations were increased as early as day 6 and continued to increase until day 17 for the 200 and 300 mg iron treatments. Body weight, other hematological measures, and tissue iron content were greater for pigs that received an iron injection at birth.

**Implications:** Pigs that did not receive an iron injection shortly after birth developed IDA resulting in poor growth, low blood hematological measures, and depleted tissue iron reserves. Supplying an iron injection at birth improved preweaning and postweaning growth performance and CBC profile. The magnitude and timing of peak hematological responses was dose dependent.

**Keywords:** swine, iron dextran, iron injection, iron deficiency, dosage

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**Resumen - Efectos de la dosis de hierro administrada a lechones recién nacidos en medidas hematológicas, el rendimiento del crecimiento antes y después del destete y el contenido de minerales tisulares después del destete**

**Objetivo:** Evaluar el desempeño de la dosis de hierro administrada al nacimiento sobre el rendimiento del crecimiento de los cerdos, la trayectoria del perfil sanguíneo antes y después del destete, y la concentración de minerales tisulares después del destete.

**Materiales y métodos:** A los cerdos híbridos (n = 70) se les asignó 1 de 5 dosis de hierro (0, 50, 100, 200, y 300 mg de hierro) administradas por inyección el día 0. El peso corporal y las muestras de sangre se recogieron el día 0, 1, 2, 3, 4, 6, 8, 11, 17, 22, 23, 24, 25, 29, 38, y 52. Todas las muestras de sangre se analizaron para determinar el perfil del conteo de células completo (CBC). Los días 22, 38, y 52, se obtuvieron tejidos de 3 cerdos por tratamiento para el análisis de minerales traza (Fe, Zn, Cu, y Mn).

**Resultados:** Los cerdos que no recibieron hierro al nacer tuvieron el crecimiento más lento y el perfil hematológico más bajo, lo que demuestra que se indujo anemia por deficiencia de hierro (IDA). Las concentraciones de hemoglobina aumentaron desde el día 6 y continuaron aumentando hasta el día 17 para los tratamientos de hierro de 200 y 300 mg. El peso corporal, otras medidas hematológicas y el contenido de hierro en los tejidos fueron mayores en los cerdos que recibieron una inyección de hierro al nacer.

**Implicaciones:** Los cerdos que no recibieron una inyección de hierro poco después del nacimiento desarrollaron IDA que resultó en un crecimiento deficiente, medidas hematológicas bajas en la sangre y reservas tisulares de hierro consumidas. El suministro de una inyección de hierro al nacer mejoró el crecimiento y el perfil de CBC antes y después del destete. La magnitud y el momento de las respuestas hematológicas máximas dependieron de la dosis.

**Résumé - Effets de la dose de fer administrée aux porcelets nouveau-nés sur les paramètres hématologiques, les performances de croissance avant et après le sevrage et la teneur en minéraux des tissus après le sevrage**

**Objectif:** Évaluer l'effet de la dose de fer administrée à la naissance sur les performances de croissance des porcs, l'évolution du profil sanguin avant et après le sevrage et la concentration minérale tissulaire après le sevrage.

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Chevalier TB, Moneque HJ, Lindemann MD. Effects of iron dosage administered to newborn piglets on hematological measures, preweaning and postweaning growth performance, and postweaning tissue mineral content. *J Swine Health Prod*. 2021;29(4):189-199.

**Matériels et méthodes:** Des porcs croisés (n = 70) ont été répartis en cinq groupes selon les doses de fer (0, 50, 100, 200, et 300 mg de fer) administrées par injection le jour 0. Le poids corporel et des échantillons de sang ont été prélevés au jour 0, 1, 2, 3, 4, 6, 8, 11, 17, 22, 23, 24, 25, 29, 38, et 52. Tous les échantillons sanguins ont été analysés pour une formule sanguine complète (CBC). Aux jours 22, 38, et 52, des tissus de trois porcs par traitement ont été obtenus pour l'analyse des oligo-éléments (Fe, Zn, Cu, et Mn).

**Résultats:** Les porcs ne recevant pas de fer à la naissance avaient la croissance la plus lente et le profil hématologique le plus bas, démontrant que l'anémie ferriprive (IDA) était induite. Les concentrations d'hémoglobine étaient augmentées dès le jour 6 et ont continué d'augmenter jusqu'au jour 17 pour les traitements de 200 et 300 mg de fer. Le poids corporel, les autres mesures hématologiques et la teneur en fer tissulaire étaient plus élevés chez les porcs ayant reçu une injection de fer à la naissance.

**Implications:** Les porcs n'ayant pas reçu d'injection de fer peu de temps après la naissance ont développé une IDA, ce qui a entraîné une croissance médiocre, de faibles valeurs hématologiques sanguines et une diminution des réserves de fer tissulaires. Fournir une injection de fer à la naissance a amélioré les performances de croissance avant et après le sevrage et le profil sanguin. L'ampleur et le moment des réponses hématologiques maximales dépendaient de la dose.

It is currently common practice to provide newborn piglets with supplemental iron usually through an intramuscular (IM) injection of an iron complex to prevent iron deficiency. Piglets are born with very low iron stores (approximately 50 mg of iron) and only receive approximately 1 mg of iron each day from sow milk.[1] Litter size and piglet growth have improved in current commercial swine production, which suggests the possibility that the traditional iron injection recommendation may not meet the requirements for modern piglets. It has previously been demonstrated that the standard 100 to 200 mg iron injection administered early in life is not sufficient to meet the individual requirements of all pigs, with the faster growing pigs at weaning having the greatest risk of becoming deficient.[2-4] Depending on the growth and metabolism of the pig, it has been suggested that a pig needs approximately 67 mg of iron per kg of body weight (BW) gain.[5] Others have suggested that under current commercial production conditions, where a pig has a normal growth of 5 to 6 kg in a 21-day period, around 310 to 380 mg of iron is required.[6] Therefore, pigs may start to become iron deficient right before weaning in production systems that only supplement 100 to 200 mg iron at birth leading to an iron gap, which is characterized by depleted iron stores before an adequate supply of iron can be absorbed from the nursery diet.[6,7] There has been additional work that shows the importance of higher hemoglobin concentrations at weaning and how it can lead to improved performance during the postweaning period.[8] It has been estimated that the economic impact of iron deficiency in the US swine industry is between $46 million to $335 million.[9] Thus, the objective of this experiment was to evaluate the effect of injectable iron dextran dosage administered at birth on pig growth performance, the course of the preweaning and postweaning blood profile, and postweaning tissue mineral concentration.

## Materials and methods

This experiment was conducted at the University of Kentucky Swine Research Center under protocols approved by the Institutional Animal Care and Use Committee of the University of Kentucky.

### Animals and experimental design

A total of 70 crossbred pigs [32 barrows and 38 gilts; (Yorkshire × Landrace) × Large White] from 7 litters were used. The experiment began in January 2019 and lasted for a total of 52 days. At birth (day 0) piglets were weighed and randomly allotted (random integer generator; Randomness and Integrity Services Ltd) within litters to 5 different iron dextran injection treatments (14 pigs/treatment) in a randomized complete block design using BW and sex as a factor. Treatments consisted of 0, 50, 100, 200, and 300 mg iron dextran (100 mg/mL; Henry Schein Animal Health) administered by IM injection in the right trapezius muscle on day 0. Iron injection treatments were administered by the same individual using a 5 mL syringe with a 20-gauge × 1-inch needle to minimize application variation and backflow. A total of 50 pigs from 5 litters that farrowed on the same day were used for blood sampling, these same pigs were used for each blood collection day. Pigs from the remaining 2 litters were used for measurement of tissue mineral content. On days 22 (weaning), 38, and 52, a total of 15 pigs (3 pigs/treatment) for each time point were euthanized. Pigs selected for tissue collection on day 22 consisted solely of the pigs not used for blood collection. On day 38 and 52, the pigs selected for tissue collection were selected from all remaining pigs based on best representation of the treatment BW average. After the day of iron administration, all personnel responsible for caring for the pigs and blood collection were blinded to pig treatment allotment.

### Housing and diets

Piglets were housed in individual farrowing crates (1.52 × 2.13 $m^2$) with their respective dam in an environmentally controlled room for the first 22 days of the experiment. On day 0 (within approximately 16 hours of birth), all pigs underwent litter processing (weighing, ear notching, needle teeth clipping, and tail docking), blood sampling, and then were administered the assigned iron dosage treatment. All male pigs were castrated on day 8 of the experiment.

The sow lactation diet was provided *ad libitum* and was formulated to supply an added 100 mg/kg iron as ferrous sulfate (Table 1). On day 22 all piglets were weaned to a nursery facility and 4 to 5 pigs were allotted per pen (1.22 × 1.22 $m^2$) based on BW and treatment. Pigs were penned by treatment to assure that the pigs that had received 0 mg iron at birth (and presumed to be anemic) were not bullied by pigs presumed to not be anemic. Each group of pigs were randomly allotted to pens (3 pens/treatment) located throughout the nursery room. The nursery diets fed post weaning were formulated to meet or exceed the nutrient requirements (NRC, 2012) of 7 to 25 kg growing pigs, which included an added 100 mg/kg iron as ferrous sulfate.

## Measurements and sample collection

Blood samples were taken on day 0, 1, 2, 3, 4, 6, 8, 11, 13, 17, 22, 23, 24, 25, 29, 38, and 52. Body weight was also recorded on these days and on day 44. Blood samples (3 mL) were collected by vena cava puncture into EDTA-containing tubes (Becton, Dickinson, and Company). Samples were later analyzed for a complete blood count (CBC) at the University of Kentucky Veterinary Diagnostic Laboratory using a hematological analyzer (Forcyte Veterinary Hematology Analyzer, Oxford Science). The CBC consisted of hemoglobin (Hb), hematocrit (HCT), red blood cell count (RBC), white blood cell count (WBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Tissue samples (liver, spleen, and heart) were collected from 3 pigs/treatment on day 22, 38, and 52. All tissues were ground and mixed to a homogenous mixture, and a subsample was digested by a microwave digester using nitric acid and procedures recommended by the manufacturer (MARS 6; CEM Corporation). After digestion, tissue digests were appropriately diluted and analyzed for trace mineral content (Fe, Zn, Cu, and Mn) using flame atomic absorption spectrophotometry (Thermoelemental, SOLAAR M5; Thermo Electron Corp). Samples were submitted by code to the laboratories thereby blinding laboratory personnel to treatment identity.

**Table 1:** Composition of sow lactation and piglet nursery diets (as-fed basis)

| | | Nursery | |
|---|---|---|---|
| **Item** | **Sow lactation** | **Phase I** | **Phase II** |
| **Ingredient, %** | | | |
| Corn | 69.57 | 50.55 | 57.46 |
| Soybean meal, 48% CP | 27.00 | 28.50 | 32.50 |
| Grease, choice white | - | 2.00 | 2.00 |
| Fish meal (Menhaden) | - | 5.00 | 0.00 |
| Spray-dried animal plasma | - | 2.00 | 0.00 |
| Whey dried | - | 10.00 | 5.00 |
| L-Lysine•HCl | 0.04 | 0.07 | 0.24 |
| DL-Methionine | - | 0.05 | 0.13 |
| L-Threonine | - | 0.07 | 0.14 |
| Dicalcium phosphate | 1.60 | 0.33 | 0.97 |
| Limestone | 0.90 | 0.77 | 0.90 |
| Salt | 0.50 | 0.50 | 0.50 |
| Trace mineral premix* | 0.10 | 0.10 | 0.10 |
| Vitamin premix† | 0.10 | 0.04 | 0.04 |
| Santoquin‡ | 0.02 | 0.02 | 0.02 |
| Other§ | 0.17 | - | - |
| **Total** | **100.00** | **100.00** | **100.00** |
| **Calculated Composition** | | | |
| Metabolizable energy, kcal/kg | 3298.00 | 3423.00 | 3404.00 |
| Crude protein, % | 18.66 | 23.79 | 21.22 |
| SID Lysine, % | 0.87 | 1.35 | 1.23 |
| Calcium, % | 0.84 | 0.80 | 0.70 |
| STTD Phosphorus, % | 0.40 | 0.36 | 0.29 |

* Mineral inclusion per kg of all diets: 50 mg of Mn as manganous sulfate, 100 mg of Fe as ferrous sulfate, 125 mg of Zn as zinc sulfate, 18 mg of Cu as copper sulfate, 0.35 mg of I as calcium iodate, and 0.30 mg of Se as sodium selenite.

† Vitamin inclusion per kg of nursery diet: 9361 IU of vitamin A; 2342 IU of vitamin D3; 62.3 IU of vitamin E; 6.9 mg of vitamin K; 0.026 mg of vitamin B12; 20.9 mg of pantothenic acid; 4.16 mg of riboflavin, 0.23 mg of biotin; 0.17 mg of folic acid; 41.5 mg of niacin; 4.16 mg of vitamin B6; and 1.15 mg of thiamin.

‡ Santoquin (Monsanto) supplied 130 mg ethoxyquin/kg of diet.

§ Includes Chromax (a source of Cr), choline chloride (60%), and copper sulfate supplied at 0.05, 0.10, 0.02 % of the lactation diet (as-fed basis), respectively.

CP = crude protein; SID = standardized ileal digestible; STTD = standardized total tract digestible.

### Statistical analysis

Growth performance and tissue data were analyzed by analysis of variance for a randomized complete block design using PROC GLM of SAS (version 9.4, SAS Institute Inc). Models originally included the treatment and the litter of origin with the pig being the experimental unit. Because the litter of origin was not significant ($P > .10$), it was subsequently dropped from the model. All hematological data were subjected to repeated measures analysis to detect the effect of treatment, day, and treatment × day interaction using PROC MIXED of SAS with an autoregressive covariance structure. Data were evaluated for statistical outliers within each treatment and day using the Grubb's test outlier calculator (GraphPad Software) but were not detected. Orthogonal polynomial contrasts were used to further determine linear and quadratic treatment effects (ie, increasing iron dosage). All data are reported as least squares means with statistical differences being considered significant at $P < .05$ and a tendency at $P < .10$.

## Results

Early during the experiment (day 4), 1 pig from the 200 mg iron injection treatment group died resulting in growth performance means of 13 pigs for that treatment.

### Growth performance

Pigs that did not receive an iron injection at birth had the lowest numerical BW by day 8 that continued through day 52 (Table 2). The low BW is a function of a low cumulative average daily gain (ADG) of the control pigs. By week 2 (day 9-14) there was a quadratic increase in ADG as iron injection dosage increased. At week 3 (day 15-22) the differences in ADG between treatments were more noticeable. Average daily gain continued to be improved in a linear and quadratic fashion through weeks 4 and 5 (day 23-29 and 30-38; the first two weeks post weaning). There were no differences in ADG thereafter; however, the linear and quadratic increase ($P = .01$) remained for overall ADG (day 0-52). The improved ADG associated with increasing iron dosage resulted in statistically heavier BW seen first at weaning (day 22). The BW response to increasing iron dosage remained linear and quadratic ($P \leq .01$) from day 23 to day 52.

### Hematological measures

In addition to poor growth performance, pigs that received no iron injection had the lowest Hb concentration at all sampling times except for day 52 by which time it recovered (Figure 1). A treatment effect, day effect, and treatment × day interaction ($P < .001$; Figure 1) was observed for Hb concentrations. Both the 50 and 100 mg iron dosages had absolute Hb concentrations that peaked at day 6 whereas the Hb concentration for the 200 and 300 mg iron treatments peaked at day 17. Similarly, HCT, RBC, WBC, MCV, MCH, and MCHC were all impacted by the iron dosage as there was a treatment effect, day effect, and treatment × day interaction ($P < .01$; Figures 2 and 3).

The 0 mg iron dosage treatment had the lowest HCT and RBC values throughout the experiment except for day 52 by which time it recovered. However, for MCV and MCH measures these same pigs seem to begin to recover earlier around day 29. The 0 mg iron dose pigs showed elevated MCHC values leading up to day 11 whereupon they decline and then recover by day 38.

### Tissue mineral measures

A total of 3 pigs/treatment/sampling period were used to determine the mineral content of liver, spleen, and heart tissues. Liver iron content (Table 3) was higher in response to increasing iron dosage at weaning (day 22) and day 38 ($P = .004$ and $P = .02$, respectively). Also, at weaning, pigs in the 300 mg iron treatment had liver iron content about 17 times greater than the pigs not receiving iron. Liver zinc content also increased ($P = .01$) with increasing iron treatments at day 52.

Similarly, the spleen exhibited an increase in iron content ($P = .003$) at weaning. However, there was a decrease in spleen zinc content ($P = .03$) as iron dosage increased with a tendency ($P = .08$) to decrease quadratically with the 200 mg iron treatment having the largest reduction, which thereafter was increased (Table 4). At day 38, the relative weight of the spleen to the BW of the pig decreased ($P = .02$) as iron dosages increased. An increase ($P = .04$) in spleen iron content as iron dosage increased was observed again at day 52. Also, at day 52, there was a numerical decrease in spleen zinc content in pigs receiving 0 through 200 mg iron dosage but an increase observed for the 300 mg iron dosage treatment. Over the tissue collection periods of the experiment (days 22, 38, and 52), liver and spleen iron content continually increased over time for pigs receiving 0 to 200 mg iron dosages. However, the 300 mg iron dosage treatment was different as liver and spleen iron content decreased over time. Lastly, the liver and spleen zinc and copper content were much lower on day 52 for all treatments compared to the content at weaning.

There was an increase in the heart iron content ($P = .01$) as iron injection increased (Table 5). Moreover, there was a linear and quadratic decrease in the absolute ($P = .01$ and $P = .02$, respectively) and relative weight ($P = .001$ and $P = .01$, respectively) of the heart at weaning as iron dosages increased. The linear and quadratic effects of decreasing relative heart weight with increasing iron dosages continued to day 38 ($P = .01$ and $P = .004$, respectively), but there were no differences in heart size by day 52. The pigs receiving no iron had the greatest relative heart weights at both weaning and day 38.

## Discussion

Increasing iron dosages at birth resulted in increased growth performance during the preweaning and postweaning periods. The improved growth in the present experiment was mostly noticed during days 15 to 22, which was the week preceding weaning, and the first 2 weeks of the nursery period (days 23-38). The days leading up to weaning (days 17-21) have been shown to be important in regard to hematological measures declining below optimal levels after receiving a standard iron injection administered early in life.[2-4] It has also been observed that optimal iron status (Hb > 11 g/dL) at weaning may lead to improved growth performance in the subsequent nursery period.[8] The positive growth performance that may be associated with optimal iron status may be attributed to improved oxygen transport, immune function, vitality, and metabolism.[10] In the current experiment, the improved growth observed around weaning and after weaning was associated with an improvement in the iron status via increasing the iron dosage at birth.

A similar study[11] looking at administration of increasing amounts of injectable iron (0, 50, 100, 150, and 200 mg iron) at processing also resulted in linear and quadratic improvements ($P < .001$) in ADG from day 3 to 21 with the 100 mg

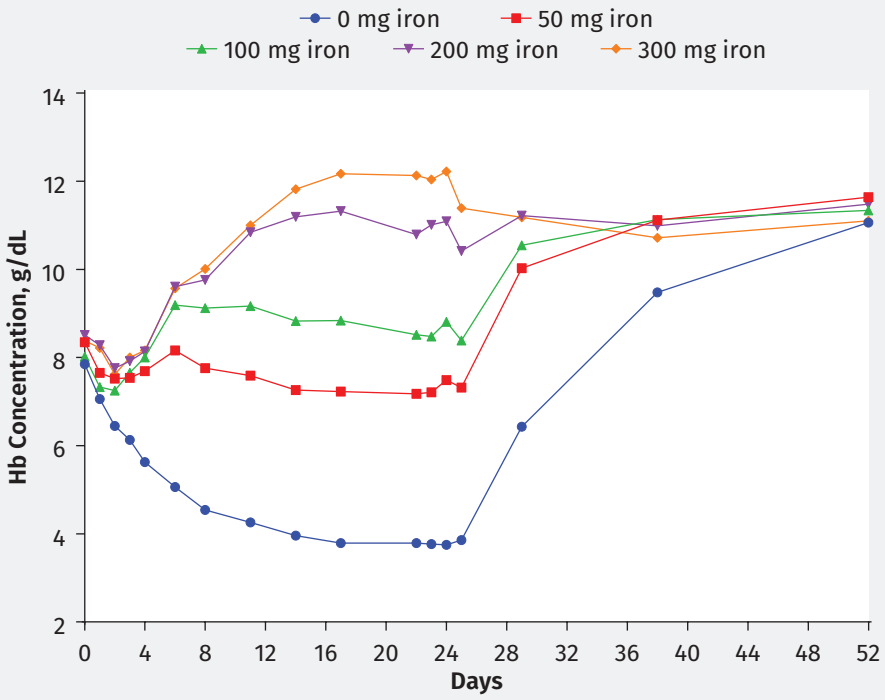
**Table 2:** Least squares means of individual preweaning and postweaning BW and ADG by iron dosage*

| | Iron dosage, mg | | | | | | *P* value | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 200 | 300 | SEM | L | Q |
| **BW, kg** | | | | | | | | |
| d 0 | 1.45 | 1.45 | 1.44 | 1.46 | 1.49 | 0.05 | .51 | .73 |
| d 1 | 1.60 | 1.58 | 1.56 | 1.63 | 1.64 | 0.06 | .42 | .63 |
| d 2 | 1.76 | 1.74 | 1.71 | 1.77 | 1.86 | 0.07 | .20 | .26 |
| d 3 | 1.96 | 1.93 | 1.93 | 1.98 | 2.06 | 0.07 | .22 | .42 |
| d 4 | 2.13 | 2.10 | 2.11 | 2.15 | 2.25 | 0.08 | .15 | .40 |
| d 6 | 2.55 | 2.53 | 2.59 | 2.59 | 2.70 | 0.08 | .14 | .63 |
| d 8 | 2.97 | 3.01 | 3.08 | 3.05 | 3.19 | 0.10 | .10 | .92 |
| d 11 | 3.57 | 3.76 | 3.84 | 3.73 | 3.89 | 0.12 | .12 | .60 |
| d 14 | 4.20 | 4.55 | 4.59 | 4.51 | 4.64 | 0.15 | .11 | .31 |
| d 17 | 4.75 | 5.33 | 5.35 | 5.32 | 5.34 | 0.18 | .08 | .09 |
| d 22 | 5.48 | 6.69 | 6.62 | 6.67 | 6.63 | 0.25 | .01 | .01 |
| d 23 | 5.27 | 6.44 | 6.44 | 6.51 | 6.39 | 0.24 | .01 | .01 |
| d 24 | 5.44 | 6.93 | 6.87 | 6.93 | 6.77 | 0.26 | .01 | .001 |
| d 25 | 5.60 | 7.28 | 7.24 | 7.34 | 7.09 | 0.27 | .004 | < .001 |
| d 29 | 6.87 | 8.81 | 8.88 | 9.12 | 8.72 | 0.32 | .002 | < .001 |
| d 38 | 10.87 | 13.91 | 14.02 | 14.15 | 14.12 | 0.49 | < .001 | < .001 |
| d 44 | 14.90 | 17.53 | 18.03 | 18.37 | 18.20 | 0.65 | .002 | .01 |
| d 52 | 20.14 | 22.77 | 24.02 | 23.48 | 23.51 | 0.77 | .01 | .01 |
| **ADG, g** | | | | | | | | |
| d 0-8 | 189.7 | 195.5 | 205.0 | 199.2 | 212.3 | 7.92 | .06 | .89 |
| d 9-14 | 204.7 | 257.3 | 250.8 | 241.9 | 241.3 | 12.39 | .26 | .04 |
| d 15-22 | 160.1 | 266.7 | 253.4 | 271.2 | 247.1 | 18.96 | .01 | .001 |
| d 23-29 | 199.2 | 303.8 | 323.3 | 349.0 | 299.4 | 19.49 | .002 | < .001 |
| d 30-38 | 445.0 | 566.4 | 571.8 | 559.0 | 599.4 | 24.94 | < .001 | .05 |
| d 39-44 | 616.6 | 641.6 | 665.2 | 692.2 | 683.9 | 39.05 | .14 | .44 |
| d 45-52 | 748.2 | 747.9 | 855.1 | 730.0 | 758.2 | 40.13 | .76 | .34 |
| d 23-52 | 504.8 | 558.1 | 597.6 | 580.5 | 576.9 | 21.93 | .04 | .02 |
| d 0-52 | 366.6 | 418.5 | 442.8 | 430.9 | 432.4 | 14.72 | .01 | .01 |

* A total of 10 pigs/treatment were assigned to 1 of 5 iron dosages administered on day 0. All pigs were weaned on day 22. Day 44 and 52 means are representative of 8 pigs/treatment.

BW = body weight; ADG = average daily gain; L = linear; Q = quadratic.

**Figure 1:** Effects of iron dosage on preweaning and postweaning hemoglobin (Hb) concentration. Iron dosages were administered on day 0 in the form of iron dextran, all pigs were weaned on day 22. Data was subjected to ANOVA by repeated measures and reported as least squares means from 10 pigs/treatment on all days except day 52 (8 pigs/treatment). There was a treatment, day, and treatment × day interaction ($P < .001$).




iron dosage showing the greatest increase and no further improvement thereafter. Somewhat similar, increasing the injectable iron dosage at birth in the current experiment led to a linear increase during week 1, which was later observed again in week 3 alongside a quadratic response with the biggest improvement observed for the 200 mg iron dose.

Overall, pigs not receiving an iron supplement (0 mg iron) demonstrated the lowest growth performance which led to the lowest final BW. This poor growth performance from the 0 mg iron injection group was accompanied by lower CBC measures by day 4 for all measures except MCHC demonstrating that iron deficiency anemia (IDA) was induced as planned by the experimental design.

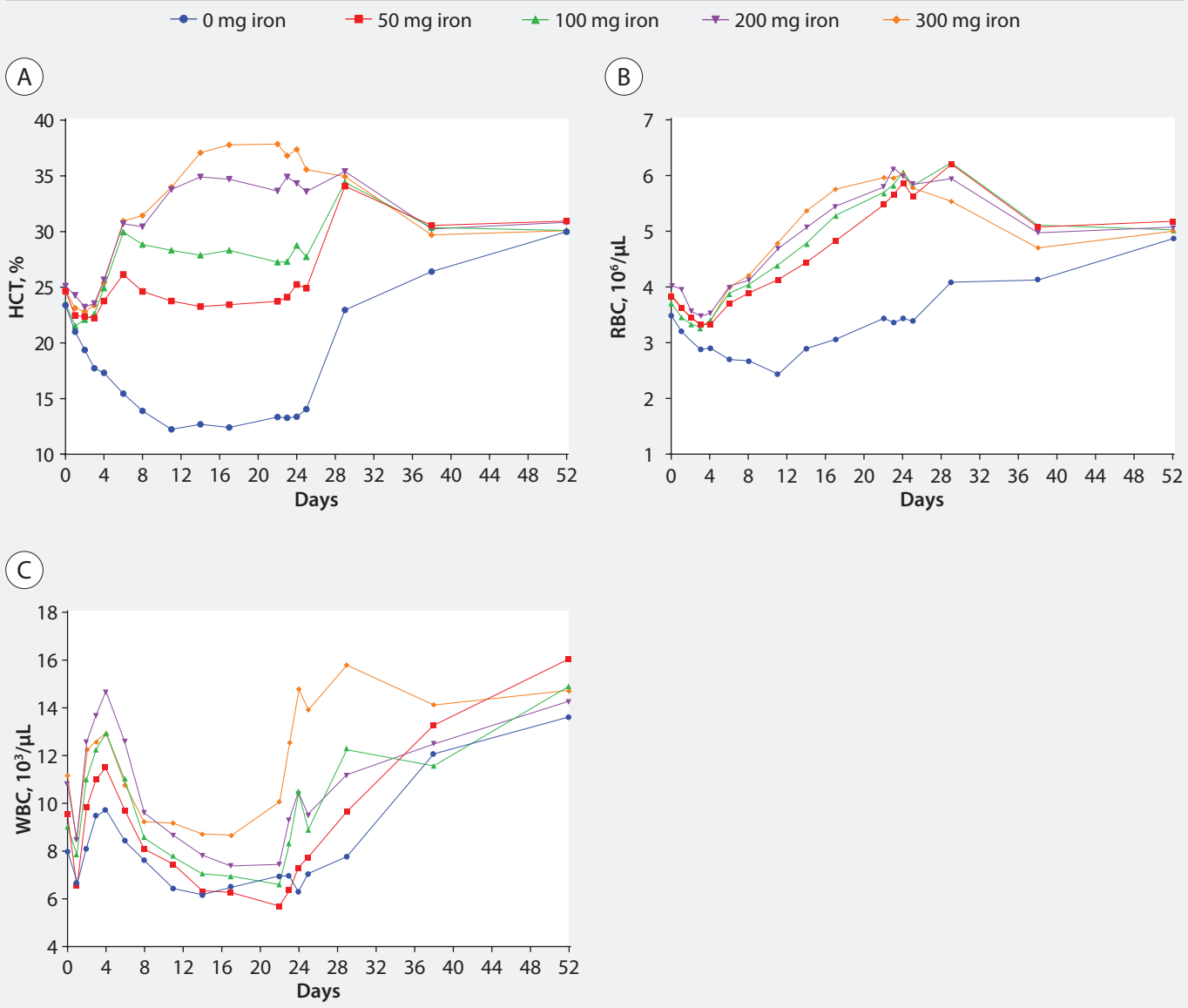
It is proposed that an IM injection of iron dextran is absorbed by the body relatively fast through the reticuloendothelial system due to the phagocytes in the liver, spleen, and bone marrow.[12] The absorbed iron is then reserved in storage sites and is subsequently transported to bone marrow for Hb synthesis, a process that can take several days in total. This may explain why there was an improvement in Hb and HCT in the current experiment at around day 4 and 6 that continued to increase until around weaning (day 22).

Pigs that received the 0 and 50 mg iron dosages were below the *Schlam's Veterinary Hematology*[13] reference range for Hb concentration (10-16 g/dL) until day 38 and day 29, respectively. Iron deficiency anemia is often defined as an Hb concentration below 9 g/dL.[3,4,13] In the current experiment, both the 0 and 50 mg iron injection treatments had Hb concentrations that were below this anemic classification for most of the experiment. On day 6 the pigs receiving 100, 200, and 300 mg iron dosages had Hb concentrations that surpassed the anemic status. Although pigs in the 100 mg iron treatment later dipped below 9 g/dL on day 14 which lasted until day 29, the pigs receiving 200 and 300 mg iron remained in the Hb reference range for the entirety of the study.

Mean corpuscular hemoglobin concentration is the Hb concentration within the red blood cell usually indicating the oxygen-carrying capacity of the blood. Different from all other CBC measurements for the control pigs, MCHC increased from day 6 to 11. However, the MCHC suddenly decreased from day 11 to 29. Data reported by Egeli et al[14] demonstrated that anemic pigs supplied with no iron at birth have higher MCHC values at day 21 than pigs that received an iron injection. This would explain and agree with the current experiment where an increase in MCHC was observed from day 6 to 11 in pigs that did not receive an iron injection. Given that total oxygen carrying capacity would be a function of the RBC and the MCHC, it is proposed that the lower RBC in pigs not receiving iron at birth may cause the body to compensate by loading the red blood cells with the hemoglobin that is present. From day 17 through 29 there was an increase in MCHC with increasing iron dosage, this improvement is simply explained by the other improvements in CBC measurements associated with increasing iron dosage that all contribute to an overall improved hematological profile. The elevated MCHC for the noninjected pigs is particularly interesting because it seems that these pigs are demonstrating a biological compensation for the lack of body iron until it is physically incapable of doing so (after day 11) where it then suddenly decreases. Thus, the initial response is to increase MCHC until such time that it is no longer possible and then it declines. While iron toxicity is always a concern when supplying greater doses of iron, within the conditions of the current experiment, supplying 300 mg of iron dextran at birth did not show any of the classical clinical signs of iron toxicity (lethargy, edema around injection site, muscle convulsions, and sudden death).

In the current experiment, the iron content of the liver, spleen, and heart at weaning increased as the injectable dosage at birth increased. The liver and spleen are major sites for ferritin and hemosiderin which are iron storage compounds that act as a reserve and are used for hemoglobin synthesis.[15] Thus why there was a linear response to iron dosages for liver and spleen iron content at weaning. Iron transport through the body is dependent on the transport protein transferrin. Transferrin delivers iron at a rate dependent on the pace of red blood cell production which is dependent on the overall iron status of the individual.[16] This concept may explain why in the present study there were greater concentrations of iron in tissues of those pigs receiving greater iron dosages.

**Figure 2:** Effects of iron dosage on preweaning and postweaning A) hematocrit (HCT), B) red blood cell count (RBC), and C) white blood cell count (WBC). Iron dosage treatments were administered on day 0 in the form of iron dextran, all pigs were weaned on day 22. Data were subjected to ANOVA by repeated measures and reported as least squares means from 10 pigs/treatment on all days except day 52 (8 pigs/treatment). There was a treatment, day, and treatment × day interaction ($P < .01$) for HCT, RBC, and WBC.




At weaning, the heart was larger for pigs receiving no supplemental iron. Due to the low amount of Hb or oxygen in the blood of anemic pigs, it is proposed that the heart must compensate and increase output to deliver more blood and oxygen to tissues. These results are supported by Dallman[15] who described that severe anemia leads to cardiac hypertrophy as observed at weaning in the current experiment.

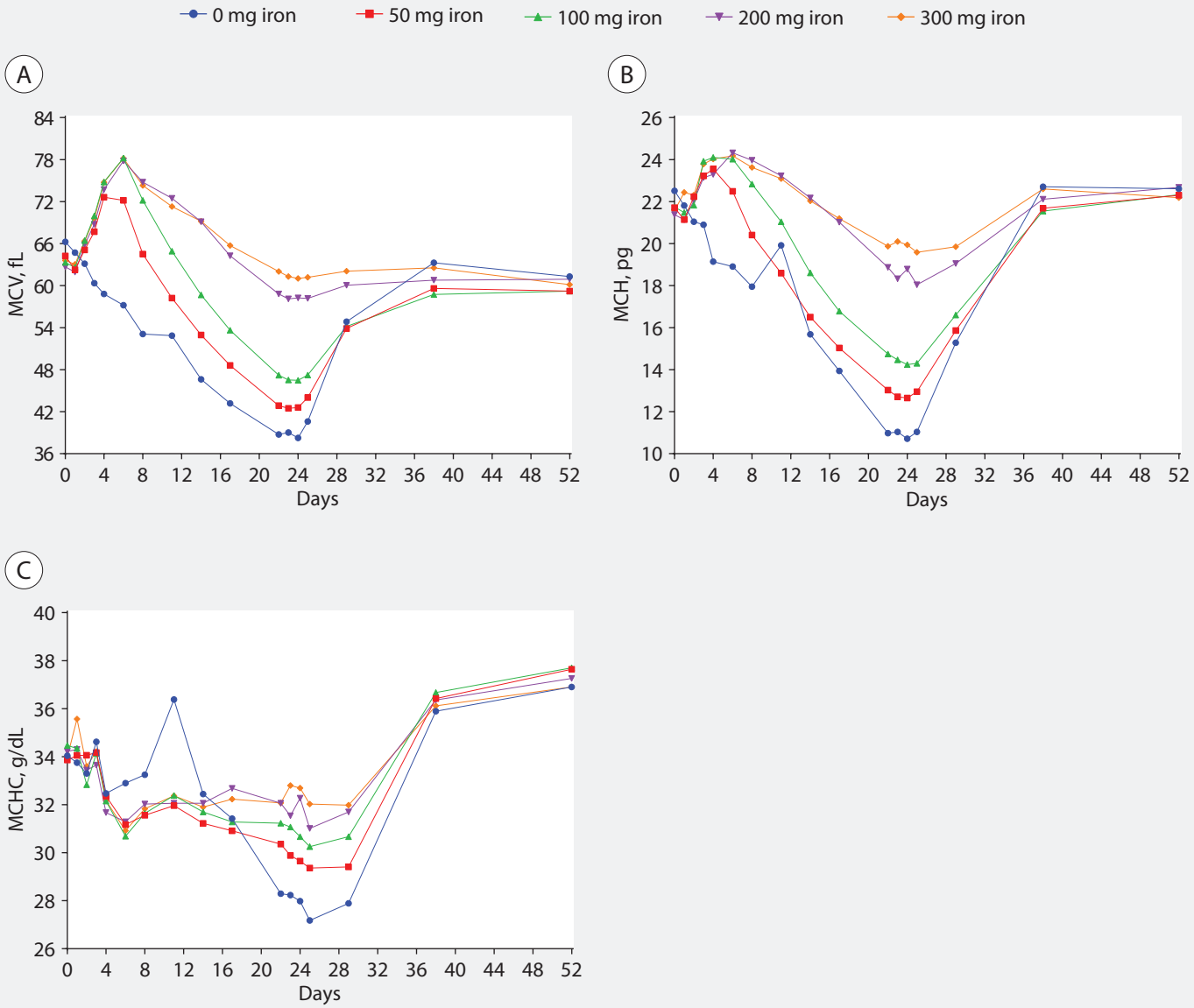
Also, at weaning, the zinc content of the spleen was reduced as iron dosage increased. Iron and zinc have been known to have competitive interaction for cellular transport especially when there are elevated iron levels.[17] Camaschella and Pagani[18] demonstrated that with higher iron concentrations in the body, zinc transporter protein 14 (ZIP14) will transport iron into hepatocytes and other cells. This could also explain the trend for a decrease in liver zinc content observed at day 38, which later increased by the end of the experiment (day 52). The liver and hepatocytes may still be processing the higher iron concentrations observed at weaning, but once the iron concentrations are under control (observed at day 38) the liver and hepatocytes can then start to compensate for the lower zinc concentrations leading to the increase in zinc concentrations by day 52.

## Implications

Under the conditions of this study:

- With no supplemented iron injection, piglets develop IDA shortly after birth.
- An iron injection at birth improves overall growth and CBC profile of piglets.
- Iron dosage impacts the magnitude and timing of peak hematological responses.

**Figure 3:** Effects of iron dosage on preweaning and postweaning A) mean corpuscular volume (MCV), B) mean corpuscular hemoglobin (MCH), and C) mean corpuscular hemoglobin concentration (MCHC). Iron dosage treatments were administered on day 0 in the form of iron dextran, all pigs were weaned on day 22. Data were subjected to ANOVA by repeated measures and reported as least squares means from 10 pigs/treatment on all days except day 52 (8 pigs/treatment). There was a treatment, day, and treatment × day interaction ($P < .01$) for MCV, MCH, and MCHC.





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### Conflict of interest

None reported.

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**Table 3:** Least squares means of liver mineral content* by iron dosage†

| | Iron dosage, mg | | | | | | *P* value | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 200 | 300 | SEM | L | Q |
| **D 22** | | | | | | | | |
| BW, kg | 6.39 | 6.61 | 5.03 | 6.20 | 6.04 | 0.53 | .71 | .37 |
| Liver WT, g | 193.03 | 223.70 | 159.17 | 213.15 | 214.97 | 18.46 | .44 | .48 |
| Liver WT, % BW | 3.03 | 3.40 | 3.18 | 3.43 | 3.58 | 0.21 | .13 | .91 |
| Fe | 95.8 | 143.0 | 204.5 | 402.9 | 1652.5 | 348.73 | .004 | .15 |
| Zn | 287.8 | 247.6 | 296.9 | 211.5 | 276.0 | 23.75 | .47 | .26 |
| Cu | 413.6 | 415.6 | 482.8 | 448.1 | 413.7 | 56.34 | .99 | .43 |
| Mn | 7.1 | 6.4 | 6.3 | 6.4 | 8.6 | 1.21 | .36 | .25 |
| **D 38** | | | | | | | | |
| BW, kg | 9.73 | 14.94 | 14.30 | 13.84 | 14.51 | 1.16 | .08 | .09 |
| Liver WT, g | 367.40 | 602.57 | 536.17 | 538.03 | 570.47 | 67.93 | .20 | .26 |
| Liver WT, % BW | 3.72 | 3.99 | 3.74 | 3.89 | 3.91 | 0.25 | .72 | .94 |
| Fe | 380.1 | 627.1 | 586.5 | 610.8 | 654.2 | 57.61 | .02 | .13 |
| Zn | 146.0 | 137.8 | 117.2 | 100.8 | 107.4 | 17.26 | .08 | .35 |
| Cu | 159.6 | 73.9 | 99.9 | 121.9 | 85.7 | 29.48 | .38 | .58 |
| Mn | 5.8 | 6.1 | 7.3 | 5.7 | 6.6 | 0.35 | .49 | .38 |
| **D 52** | | | | | | | | |
| BW, kg | 21.19 | 22.27 | 24.49 | 22.53 | 22.61 | 2.38 | .80 | .52 |
| Liver WT, g | 803.00 | 806.83 | 870.63 | 865.17 | 828.57 | 90.84 | .78 | .60 |
| Liver WT, % BW | 3.80 | 3.63 | 3.56 | 3.84 | 3.66 | 0.11 | .99 | .69 |
| Fe | 742.4 | 796.5 | 819.6 | 786.0 | 913.4 | 90.74 | .27 | .81 |
| Zn | 114.5 | 129.5 | 132.6 | 182.1 | 180.2 | 17.78 | .01 | .58 |
| Cu | 35.5 | 25.2 | 35.1 | 33.3 | 30.1 | 3.81 | .80 | .90 |
| Mn | 4.2 | 5.5 | 3.3 | 2.8 | 3.1 | 0.67 | .06 | .54 |

* Mineral content is reported as mg/kg of tissue as measured on a dry matter basis.

† Pigs were administered 1 of 5 iron dosages on day 0. All pigs were weaned on day 22. A total of 3 pigs/treatment were used for tissue analysis at day 22, 38, and 52.

BW = body weight; WT = weight; L = linear; Q = quadratic.


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**Table 4:** Least squares means of spleen mineral content* by iron dosage†

| | Iron dosage, mg | | | | | | *P* value | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 200 | 300 | SEM | L | Q |
| **D 22** | | | | | | | | |
| BW, kg | 6.39 | 6.61 | 5.03 | 6.20 | 6.04 | 0.53 | .71 | .37 |
| Spleen WT, g | 15.63 | 18.43 | 16.83 | 25.15 | 17.67 | 3.37 | .39 | .25 |
| Spleen WT, % BW | 0.25 | 0.28 | 0.33 | 0.40 | 0.28 | 0.06 | .37 | .09 |
| Fe | 483.6 | 665.1 | 983.0 | 1189.3 | 1149.8 | 134.59 | .003 | .10 |
| Zn | 83.5 | 81.7 | 73.4 | 62.7 | 72.8 | 4.53 | .03 | .08 |
| Cu | 7.3 | 8.2 | 6.0 | 6.3 | 6.2 | 0.96 | .17 | .58 |
| Mn | 1.47 | 1.35 | 1.34 | 1.07 | 1.56 | 0.27 | .99 | .22 |
| **D 38** | | | | | | | | |
| BW, kg | 9.73 | 14.94 | 14.30 | 13.84 | 14.51 | 1.16 | .08 | .09 |
| Spleen WT, g | 31.17 | 41.13 | 34.03 | 33.63 | 34.67 | 4.19 | .91 | .70 |
| Spleen WT, % BW | 0.32 | 0.27 | 0.24 | 0.24 | 0.24 | 0.02 | .02 | .07 |
| Fe | 581.9 | 692.1 | 643.4 | 713.4 | 644.9 | 84.13 | .66 | .42 |
| Zn | 56.0 | 67.5 | 59.4 | 56.1 | 56.5 | 6.60 | .58 | .72 |
| Cu | 4.4 | 4.5 | 3.8 | 3.7 | 3.7 | 0.40 | .16 | .49 |
| Mn | 1.17 | 1.08 | 1.06 | 1.07 | 1.14 | 0.07 | .93 | .22 |
| **D 52** | | | | | | | | |
| BW, kg | 21.19 | 22.27 | 24.49 | 22.53 | 22.61 | 2.38 | .80 | .52 |
| Spleen WT, g | 54.13 | 82.53 | 82.37 | 74.30 | 84.90 | 15.80 | .38 | .53 |
| Spleen WT, % BW | 0.28 | 0.37 | 0.33 | 0.33 | 0.39 | 0.08 | .51 | .98 |
| Fe | 774.7 | 1382.6 | 1125.7 | 1308.5 | 1571.7 | 194.75 | .04 | .68 |
| Zn | 63.6 | 44.6 | 61.0 | 48.1 | 66.0 | 7.05 | .60 | .13 |
| Cu | 3.7 | 4.6 | 4.5 | 3.8 | 5.4 | 0.41 | .07 | .41 |
| Mn | 1.07 | 0.70 | 1.04 | 0.87 | 0.98 | 0.11 | .99 | .42 |

* Mineral content is reported as mg/kg of tissue as measured on a dry matter basis.

† Pigs were administered 1 of 5 iron dosages on day 0. All pigs were weaned on day 22. A total of 3 pigs/treatment were used for tissue analysis at day 22, 38, and 52.

BW = body weight; WT = weight; L = linear; Q = quadratic.


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**Table 5:** Least squares means of heart mineral content* by iron dosage†

| | Iron dosage, mg | | | | | | *P* value | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 200 | 300 | SEM | L | Q |
| **D 22** | | | | | | | | |
| BW, kg | 6.39 | 6.61 | 5.03 | 6.20 | 6.04 | 0.53 | .71 | .37 |
| Heart WT, g | 57.50 | 46.07 | 32.97 | 42.90 | 38.67 | 3.46 | .01 | .02 |
| Heart WT, % BW | 0.90 | 0.70 | 0.66 | 0.70 | 0.65 | 0.03 | .001 | .01 |
| Fe | 163.19 | 190.56 | 341.71 | 283.96 | 379.09 | 50.11 | .01 | .49 |
| Zn | 56.60 | 61.33 | 72.03 | 65.09 | 53.32 | 7.64 | .68 | .13 |
| Cu | 10.55 | 12.48 | 13.84 | 11.79 | 10.72 | 1.18 | .65 | .11 |
| Mn | 1.33 | 1.42 | 1.49 | 1.03 | 1.21 | 0.16 | .13 | .95 |
| **D 38** | | | | | | | | |
| BW, kg | 9.73 | 14.94 | 14.30 | 13.84 | 14.51 | 1.16 | .08 | .09 |
| Heart WT, g | 72.47 | 86.23 | 77.67 | 73.43 | 81.33 | 7.25 | .86 | .97 |
| Heart WT, % BW | 0.75 | 0.58 | 0.54 | 0.53 | 0.56 | 0.03 | .01 | .004 |
| Fe | 222.72 | 281.58 | 247.58 | 243.68 | 259.03 | 28.29 | .75 | .76 |
| Zn | 59.29 | 60.09 | 55.09 | 47.95 | 55.48 | 2.99 | .08 | .10 |
| Cu | 11.95 | 13.83 | 13.97 | 11.83 | 13.47 | 0.68 | .82 | .67 |
| Mn | 1.29 | 1.35 | 1.21 | 1.08 | 1.23 | 0.11 | .34 | .39 |
| **D 52** | | | | | | | | |
| BW, kg | 21.19 | 22.27 | 24.49 | 22.53 | 22.61 | 2.38 | .80 | .52 |
| Heart WT, g | 111.40 | 108.47 | 121.20 | 118.00 | 115.23 | 12.89 | .74 | .67 |
| Heart WT, % BW | 0.55 | 0.49 | 0.49 | 0.53 | 0.51 | 0.05 | .88 | .64 |
| Fe | 294.68 | 357.50 | 345.50 | 380.64 | 320.40 | 33.82 | .65 | .12 |
| Zn | 53.81 | 47.37 | 46.79 | 52.34 | 49.40 | 3.44 | .88 | .51 |
| Cu | 16.16 | 14.65 | 14.08 | 15.87 | 14.87 | 1.46 | .87 | .69 |
| Mn | 1.58 | 1.68 | 1.35 | 1.59 | 1.43 | 0.10 | .29 | .83 |

* Mineral content is reported as mg/kg of tissue as measured on a dry matter basis.

† Pigs were administered 1 of 5 iron dosages on day 0. All pigs were weaned on day 22. A total of 3 pigs/treatment were used for tissue analysis at day 22, 38, and 52.

BW = body weight; WT = weight; L = linear; Q = quadratic.

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BRIEF COMMUNICATION PEER REVIEWED

# Late gestation hemoglobin concentrations in sows: Predictor for stillborn piglets

Elizabeth Noblett, MS; Juliana Bonin Ferriera, DVM, DVSc; Sheeva Bhattarai, MS, PhD; Jens Peter Nielsen, DVM, PhD; Glen Almond, DVM, PhD

## Summary

This study examined the association between hemoglobin (Hb) concentrations in sows and the number of stillborn pigs. Based on late gestation Hb concentrations, the number of prepartum and intrapartum stillborn pigs was greater ($P < .001$) in the anemic sows than in the nonanemic sows.

**Keywords:** swine, sow, hemoglobin, stillbirths

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**Resumen - Concentraciones de hemoglobina en gestación tardía en cerdas: Predictor de lechones nacidos muertos**

Este estudio examinó la asociación entre las concentraciones de hemoglobina (Hb) en cerdas y el número de lechones nacidos muertos. Con base en las concentraciones de Hb en gestación tardía, el número de lechones nacidos muertos antes del parto e intraparto fue mayor ($P < .001$) en las cerdas anémicas que en las no anémicas.

**Résumé - Concentrations d'hémoglobine en fin de gestation chez les truies: Prédicteur pour les porcelets mort-nés**

Cette étude a examiné l'association entre les concentrations d'hémoglobine (Hb) chez les truies et le nombre de porcs mort-nés. Sur la base des concentrations de Hb en fin de gestation, le nombre de porcs mort-nés prépartum et intrapartum était plus élevé ($P < .001$) chez les truies anémiques que chez les truies non anémiques.

Measurements of hemoglobin (Hb) concentrations are used to determine if sows are anemic. The normal Hb range in sows is 10 to 16 g/dL and less than 10 g/dL is indicative of anemia.[1] Anemia is prevalent during early lactation and Hb levels begin to trend upwards in late lactation.[2] Furthermore, parity also contributes to the occurrence of anemic sows; anemia is more common as parity increases.[3] A recent study demonstrated that the probability of stillbirths was negatively associated with sow Hb concentrations.[4] A stillborn piglet refers to a fetus that dies in utero prior to or during farrowing. Piglets that die after the birth process are simply dead piglets. This association between Hb concentrations and the number of stillborn piglets required further investigation in commercial sow farms. Therefore, the primary objective of this study was to determine the relationship between sow Hb concentrations and the number of stillborn piglets and postpartum dead piglets.

## Materials and methods

Five sow farms (3000-4000 sows/farm) were included in this study. Each farm was Pork Quality Assurance Plus certified and an Institutional Animal Care and Use Committee protocol was not required. Sows (n = 390, 45-128 sows/farm) from varying parities were selected on each farm. Blood samples were collected in late gestation (> 112 days) and within 12 h after farrowing for Hb determinations. Blood was obtained from an ear vein with a 20-gauge needle, loaded into a 10 µL microcuvette, and processed in a HemoCue Hb 201.[2,5] This instrument was factory calibrated against the International Council for Standardization in Haematology reference method for Hb concentration and did not need further calibration. Litter demographics (number of live born, stillborn, and mummies) also were recorded for each sow. Deceased piglets were dissected and lung flotation tests were performed.[6]

The Hb concentrations and litter characteristics were analyzed with an analysis of variance with the main effect being anemia. The effect of farm and parity category were analyzed in a similar fashion. Means were compared with Tukey's test (Statistix, Version 10, Analytical Software). A generalized linear model with negative binomial distribution (to account for over dispersion of data) was fitted in SAS 9.4 (SAS Institute Inc) to analyze the effect of late gestation Hb (LGHB) concentrations on number of stillborn piglets. The other variables of interest were parity, farm, piglets born alive, and number of mummified fetuses.

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## Results

Although one study used values less than 10.0 g/dL to classify anemia,[1] the study used sows in mid gestation. Using 10.3 g/dL as the Hb reference value for anemia in sows prior to farrowing as previously described,[4] 210 sows were classified as anemic in late gestation. The remaining 180 sows were considered nonanemic. The descriptive statistics for these two groups of sows are shown in Table 1. The number of prepartum and intrapartum stillborn piglets was greater ($P < .001$) in the anemic sows than in the nonanemic sows. The number of postpartum dead pigs and mummies per litter did not differ between the two classifications of sows.

The post farrowing Hb (PFHB) concentrations and number of pigs born alive, stillborn pigs, and postpartum dead pigs differed among farms (Table 2). In contrast, the LGHB concentrations were similar among farms. The LGHB concentrations were less ($P = .008$) in parity ≥ 3 sows than in parity 1 or 2 sows (Table 3). Over 79% of older parity (> 4) sows were anemic following farrowing.

The multivariate analysis (Table 4) showed that LGHB concentrations, farm, and number of mummies were significant factors in the number of stillborn pigs. The estimate for the LGHB concentration was -0.30 and the exponential was 0.74. Thus, if a sow with 10 g/dL has two prepartum and intrapartum stillborn pigs, and if one could increase the LGHB concentration to 11 g/dL, the sow would be expected to have 2 × 0.74 = 1.48 stillborn piglets.

## Discussion

An early study found that sows in herds with a high rate of stillbirths were found to have 25% to 50% reduction in Hb concentrations.[7] Similarly, a recent study reported that the probability of stillbirths was negatively associated with the sow Hb concentrations.[4] Therefore, the results of the present study support findings in earlier reports that LGHB concentrations were associated with the occurrence of stillborn piglets. The precise mechanism to explain the relationship between sow anemia and stillbirths is speculative; however, iron deficiency may contribute to impaired uterine contractions at farrowing.[4] The low LGHB concentrations are likely due to the increase in plasma volume in sows, and at least in part, to the transfer of iron from the dam to the fetuses through the maternal uteroferrin-transferrin-ferritin pathway.[8,9]

Considering the relationship between LGHB concentrations and their ability to be used as a predictor for stillborn pigs, intervention with iron supplementation could be considered at this time. If sows were not anemic, it was apparent that iron treatment of pregnant sows did not improve sow and piglet hematology or stillbirth rate.[10] Additional studies are warranted to determine the time and concentration of iron that would be needed to counteract the deficiency. Based on the present results, this would vary with parity, farm, and from sow to sow. It should be noted that the present study demonstrated farm-to-farm variability, and this must be considered when interpreting the results or recommending corrective actions. Thus, the severity of the anemia and farm

**Table 1:** Mean (SEM) hemoglobin (Hb) concentrations and litter parameters for anemic (n = 210) and nonanemic (n = 180) sows*

| Variable | Anemic sows | Nonanemic sows |
|---|---|---|
| Late gestation Hb, g/dL | 9.3 (0.05)[a] | 11.1 (0.05)[b] |
| Post farrowing Hb, g/dL | 9.5 (0.09)[a] | 9.9 (0.09)[b] |
| Pigs born alive, No. | 13.7 (0.2)[a] | 12.9 (0.24)[b] |
| Prepartum and intrapartum stillborn/litter | 0.8 (0.1)[a] | 0.4 (0.07)[b] |
| Postpartum dead/litter | 0.2 (0.03) | 0.3 (0.06) |
| Mummies/litter | 0.4 (0.06) | 0.3 (0.04) |

* Anemia classification is based on Hb concentrations in late gestation.

[a,b] Within row, differing superscripts denote values that differ by $P < .01$.

**Table 2:** Mean (SEM) hemoglobin concentrations, number born alive, and stillbirths in five farms

| Farm | Sows, No. | LGHB, g/dL | PFHB, g/dL | Prepartum/ intrapartum stillborns, No. | Postpartum dead pigs, No. | Pigs born alive, No. |
|---|---|---|---|---|---|---|
| 1 | 81 | 10.2 (0.12) | 9.0 (0.11)[c] | 0.43 (0.12)[ab] | 0.07 (0.03)[b] | 14.0 (0.33)[ab] |
| 2 | 70 | 9.9 (0.13) | 9.6 (0.16)[b] | 0.86 (0.14)[a] | 0.10 (0.04)[b] | 12.8 (0.28)[b] |
| 3 | 128 | 10.1 (0.11) | 10.2 (0.12)[a] | 0.87 (0.13)[a] | 0.27 (0.08)[ab] | 12.9 (0.27)[b] |
| 4 | 66 | 10.2 (0.12) | 9.4 (0.14)[bc] | 0.29 (0.10)[b] | 0.12 (0.05)[b] | 14.5 (0.23)[a] |
| 5 | 45 | 10.3 (0.14) | 9.9 (0.15)[ab] | 0.49 (0.16)[ab] | 0.56 (0.15)[a] | 12.5 (0.69)[b] |

[a,b,c] Within column, values with different superscripts differ $P < .05$.

LGHB = Late gestation hemoglobin concentrations; PFHB = Post farrowing hemoglobin concentrations.

**Table 3:** Percentage of anemic sows and mean (SEM) hemoglobin concentrations in various parities of sows

| Parity category* | Sows, No. | LGHB, g/dL | Anemic sows, % | PFHB, g/dL | Anemic sows, % |
|---|---|---|---|---|---|
| 1 | 52 | 10.8 (0.14)[a] | 25.0 | 10.0 (0.17)[a] | 57.7 |
| 2 | 80 | 10.5 (0.11)[a] | 46.3 | 9.8 (0.15)[a] | 68.8 |
| 3 | 171 | 9.9 (0.09)[b] | 62.0 | 9.7 (0.11)[ab] | 70.2 |
| 4 | 87 | 9.9 (0.11)[b] | 62.1 | 9.3 (0.11)[b] | 79.3 |

* Category 1 = parity 1; Category 2 = parity 2; Category 3 = parities 3 and 4; Category 4 = greater than 4th parity.

[a,b] Within column, values with different superscripts differ $P < .01$

LGHB = Late gestation hemoglobin concentrations; PFHB = Post farrowing hemoglobin concentrations.

**Table 4:** Multivariate analysis of the late gestation Hb (LGHB) concentrations and other variables that contribute to stillborn pigs*

**Analysis of maximum likelihood parameter estimates**

| Parameter | *df* | Estimate | Standard error | Wald 95% confidence limits | | Wald chi-square | Pr > ChiSq |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | 1.87 | 0.93 | 0.05 | 3.70 | 4.04 | 0.04 |
| LGHB | 1 | -0.31 | 0.09 | -0.46 | -0.14 | 12.85 | 0.00 |
| Farm 1 | 1 | 0.21 | 0.39 | -0.56 | 0.98 | 0.29 | 0.59 |
| Farm 2 | 1 | 0.76 | 0.38 | 0.01 | 1.50 | 3.93 | 0.05 |
| Farm 3 | 1 | 0.89 | 0.36 | 0.18 | 1.61 | 6.01 | 0.01 |
| Farm 4 | 1 | -0.09 | 0.44 | -0.94 | 0.77 | 0.04 | 0.84 |
| Farm 5 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | . | . |
| Mummies | 1 | 0.38 | 0.12 | 0.14 | 0.62 | 9.27 | 0.00 |
| Dispersion | 1 | 1.63 | 0.33 | 1.09 | 2.43 | . | . |

**LR statistics for type 3 analysis**

| Source | *df* | Chi-Square | Pr > ChiSq |
|---|---|---|---|
| LGHB | 1 | 12.87 | 0.0003 |
| Farm | 4 | 16.22 | 0.0027 |
| Mummies | 1 | 10.16 | 0.0014 |

* The estimate for LGHB = -0.30 and the exponential = 0.74. The negative binomial dispersion parameter was estimated by maximum likelihood.

differences likely would dictate the timing and treatment of sows. In our modern sow facilities, it is unlikely that individual sows would be tested, and thus, alternative approaches must be considered.

## Implications

Under the conditions of this study:

- Anemia in late gestation predisposes sows to increased pre- and intrapartum stillborn pigs.
- Sows with parity ≥ 3 tend to have lower Hb concentrations than younger sows.
- Treatment, prevention, and assessment of late gestation anemia require additional studies.

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### Conflict of Interest

None reported.

### Disclaimer

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**Brief Communication** **Peer reviewed**

# Evaluation of PRRSV vaccine efficacy following infection with PRRSV 1-7-4

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## Summary

Our objective was to evaluate whether porcine reproductive and respiratory syndrome virus (PRRSV) vaccination improved mortality and morbidity following experimental infection with a PRRSV restriction fragment length polymorphism 1-7-4. Results indicated that mortality and morbidity were significantly lower for vaccinated pigs as compared to unvaccinated pigs ($P < .001$).

**Keywords:** swine, porcine reproductive and respiratory syndrome, vaccine, mortality, robustness

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**Resumen - Evaluación de la eficacia de la vacuna contra el PRRSV después de la infección por PRRSV 1-7-4**

Nuestro objetivo fue evaluar si la vacunación contra el virus del síndrome reproductivo y respiratorio del cerdo (PRRSV) mejoraba la mortalidad y la morbilidad después de una infección experimental con un PRRSV con un patrón de corte de polimorfismos de longitud de fragmento de restricción del 1-7-4. Los resultados indicaron que la mortalidad y la morbilidad fueron significativamente menores para los cerdos vacunados en comparación con los cerdos no vacunados ($P < .001$).

**Résumé - Évaluation de l'efficacité du vaccin contre le virus du SRRP après une infection par le VSRRP 1-7-4**

Notre objectif était d'évaluer si la vaccination contre le virus du syndrome reproducteur et respiratoire porcin (SRRP) améliorait la mortalité et la morbidité suite à une infection expérimentale avec de polymorphisme de longueur des fragments de restriction du PRRSV 1-7-4. Les résultats ont indiqué que la mortalité et la morbidité étaient significativement plus faibles pour les porcs vaccinés que pour les porcs non vaccinés ($P < .001$).

The porcine reproductive and respiratory syndrome virus (PRRSV) restriction fragment length polymorphism (RFLP) variant 1-7-4 is a highly virulent virus and common throughout the Midwestern United States.[1] Costs of the disease have been estimated to be $119 to $768/sow/year.[2] Typing an RFLP consists of digestion of viral nucleic acid with restriction endonucleases followed by gel electrophoresis, resulting in different gel banding patterns dependent on sequence differences among viruses.[3] These analyses indicate that the PRRSV RFLP 1-7-4 variant is diverse, with differences in the level of pathogenicity between variants.[4]

Commercially available PRRSV vaccines have been used within the swine industry for over 30 years. Two main categories of commercially available vaccines include modified-live virus (MLV) and killed-virus vaccines; however, killed-PRRSV vaccines have not been shown to effectively confer protection or prevent disease.[5] Therefore, the use of PRRS MLV vaccines is preferred due to their ability to reduce viremia and clinical signs.[5]

One limitation that affects the efficacy of PRRS MLV vaccines is the high PRRSV mutation rate.[6] The RNA-dependent RNA polymerase of PRRSV lacks 3′ proofreading ability,[7] leading to an estimated random evolution rate between $4.71 \times 10^2$ and $9.8 \times 10^2$ per synonymous site per year.[8] Therefore, it is important to determine whether commercially available PRRSV vaccines are efficacious across variants commonly found throughout the swine industry, such as PRRSV 1-7-4. Based on this approach, the objective of this study was to estimate the effect of vaccination with a commercially available PRRS MLV vaccine on mortality and morbidity rate in pigs subsequently inoculated with PRRSV 1-7-4. The study was based on the hypothesis that vaccination would improve performance and decrease mortality as compared to unvaccinated controls.

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## Materials and methods

The Pipestone Applied Research Institutional Animal Care and Use Committee approved the trial protocol, mortality standards, and caretaker handling certification (PAR IACUC 1-18). A visual assessment of pigs and their environment, including verification of food and water source, was completed daily by a caretaker under the direction of the site veterinarian. The caretaker completed daily assessment using the individual pig care scoring system that classifies animal health status.[9] The system classifies pigs as A = acute sickness, B = subacute sickness, or C = severe, chronic illness. Acute sickness was defined as a pig presenting early clinical disease signs such as inappetence, fever, and lethargy. Subacute sickness was defined as moderate disease signs, including increased anorexia and lethargy relative to class A. Severe, chronic illness was defined by severe anorexia. Pigs were treated with antibiotics if classified as B or C. If deemed immobile and unable to eat or drink, the pig was euthanized. Pigs were humanely euthanized by a qualified caretaker that had been trained by the Pipestone Welfare Department and veterinarian.

### Animal source, housing, and post weaning experimental design

All pigs (N = 198) were farrowed and weaned in the same commercial farm in southern Minnesota. Pigs were polymerase chain reaction (PCR) negative for influenza A virus of swine and PRRSV (PCR and enzyme-linked immunosorbent assay negative) prior to the study and had not been vaccinated previously for PRRSV. Viruses were sequenced at the open reading frame (ORF) 5 region to differentiate vaccine strain from wild-type variants. Standard protocols were used for PRRSV PCR testing. Further, pigs showing any disease signs (eg, diarrhea or swollen joints) were not included in the study. Individual pigs were uniquely identified with ear tags. Pigs were weaned at approximately 4 weeks of age and inoculated with PRRSV RFLP 1-7-4 at approximately 8 weeks of age. At weaning, 100 of the 198 pigs were randomly allocated at the pig level after balancing for sex (barrows and gilts) to the unvaccinated group and shipped to a research nursery in southwestern Minnesota. Pigs remaining at the source farm received a 2 mL dose of a commercial PRRS MLV vaccine following manufacturer's recommendations (Ingelvac PRRS ATP, Boehringer Ingelheim) at weaning. Two days prior to inoculation with PRRSV RFLP 1-7-4, the vaccinated group was shipped to the same research facility as the unvaccinated group. Upon arrival, pigs (N = 198) were sorted into pens by vaccine status, resulting in 8 pens of pigs per treatment group. Sex was balanced within pen. Each pen housed 12 to 13 pigs; when an odd number of pigs were placed in a pen, the extra pig was a barrow. Treatment groups were assigned to pens throughout the barn so as to account for within-barn effects.

### PRRSV RFLP 1-7-4 inoculation

One week prior to PRRSV inoculation, oral fluid sampling was collected on all pigs for PRRSV testing. Using a $2 \times 10^{3.5}$ 50% tissue culture infective dose of PRRSV lineage 1 RFLP 1-7-4, all pigs were experimentally infected intramuscularly at 28 days post vaccination.[6] Based on a previous study[1] where this same pathogenic variant of PRRSV was used, the attending veterinarian visited the research facility weekly to assess when antibiotic intervention was necessary to treat secondary bacterial infections, specifically *Streptococcus suis* and *Glasserella parasuis*. While the decision regarding antibiotic selection was made based on culture and sensitivity data from laboratory submissions, commonly used antibiotics for these two specific agents frequently consisted of penicillin and cephalosporin products. A list of pigs showing clinical signs of morbidity was created daily. Individual pigs showing signs of morbidity were treated for the disease. When the list reached 20% of the population, mass medication was administered.

### Phenotype collection

At 0, 7, and 14 days post infection (dpi), each pig was scored with a reported robustness scoring system as previously described.[10] This 5-point scoring system assigned a clinical score based on general clinical disease signs: 1 = a normal, healthy pig showing no disease signs; 2 = a pig showing early disease signs; 3 = a pig showing moderate disease signs; 4 = a pig with advanced clinical disease; or 5 = candidate for euthanasia. Individuals recording robustness scores were blinded for vaccination status. Mortalities were recorded throughout the study. This trial was terminated 4 weeks after challenge.

### Statistical analysis

This facility included 200 nursery pig spaces with 16 pens, which allowed 8 pens/treatment group. Based on a sample size calculation ($\alpha = .05$, power = 80%, and SD = 0.12) this sample size allowed for detection of a difference of 0.16 in mortality between vaccinated and unvaccinated treatment groups. Data collected from 0 to 28 dpi were analyzed using a linear fixed effects model, where vaccine status (vaccinated vs unvaccinated for PRRSV) was fitted as a fixed effect with pen (n = 16) as the experimental unit. All analyses were conducted using R software (Version 1.2.1578; The R Foundation) using the lm function. Normality and homogeneity of variance assumptions were assessed with a Shapiro-Wilks test (Shapiro.test in R) and Levene's test (leveneTest in R) where appropriate. Differences between groups were expressed as least squares means computed from the lm function of R. For the mortality and robustness score data to be analyzed at the pen level, mortality and robustness scores were averaged within pen to represent a mean percent mortality, mean robustness score at 7 dpi, and mean robustness score at 14 dpi for each pen.

## Results

The PRRS MLV vaccine was detected in the vaccinated group and not in the unvaccinated group prior to inoculation. Nucleic acid sequencing of the ORF 5 region of the vaccine virus and the PRRSV 1-7-4 challenge virus indicated an 87% homology between the two viruses. Greater than 20% of pigs showed clinical disease signs at 7 and 14 dpi; thus, mass treatment was administered at these time points. At 7 dpi, 1 mL of a ceftiofur antibiotic (Excede, Zoetis) was administered because recovery of *Streptococcus suis* and *Glasserella parasuis* and corresponding antibiotic susceptibility data indicated use of this product. At 14 dpi, the same antibiotic and 0.5 mL of an anti-inflammatory drug (Predef, Zoetis) were administered to reduce fever and respiratory signs associated with PRRSV and the secondary bacteria noted above.

Mean mortality rate in the barn was 13.6%. Mortality rates (SEM) were 5% (0.03) and 22% (0.03) for the vaccinated and unvaccinated groups, respectively ($P < .001$; Table 1). The greatest number of mortalities (79%) occurred 14 dpi. All pigs received a robustness score of 1 at day 0. Mean robustness score of the barn at 7 dpi was 2.86. Mean (SEM) robustness scores at 7 dpi were 2.59 (0.13) for the vaccinated group and 3.13 (0.13) for the unvaccinated group ($P = .01$; Figure 1A). Mean robustness score of the barn at 14 dpi was 2.65. Mean (SEM) robustness scores at 14 dpi were 2.04 (0.15) for the vaccinated group and 3.25 (0.15) for the

unvaccinated group ($P < .001$; Figure 1B). Variation in clinical robustness score was greater in the unvaccinated group (Figure 1).

## Discussion

The objective of this study was to evaluate the efficacy a PRRS MLV vaccine following experimental infection with PRRSV RFLP 1-7-4. The study was based on the hypothesis that vaccination would improve health and lower mortality as compared to unvaccinated controls. Under the conditions of the study, unvaccinated pigs demonstrated reduced robustness at both 7 and 14 dpi along with a higher mortality rate. Although the use of vaccine significantly reduced mortality and morbidity, 5% mortality was still observed in the vaccinated group, indicating the acknowledged limitations of this approach. Further, the mean robustness scores were 2.59 and 2.04 at 7 and 14 dpi, respectively. On average, vaccinated pigs had reduced clinical signs of PRRSV infection and a lower overall mortality rate, consistent with previous studies.[11,12]

Pathogens can have a major extrinsic effect on performance, resulting in increased variation in body weight for individuals within an infected herd. Previous research[12] suggests that variation in morbidity and pathogen exposure translates to weight and performance differences. Increased variation in robustness scores at 7 and 14 dpi within the unvaccinated group was consistent with previous research.

As with all studies, this project exhibited both strengths and limitations. Strengths included the use of a representative variant of PRRSV which provided a robust challenge, along with the use of a large number (approximately 100) of pigs per group. Limitations included the use of only a single variant of PRRSV, as the PRRSV RFLP 1-7-4 type is not homogenous. Different PRRSV RFLP 1-7-4 viruses caused varying levels of pathogenicity and virulence[4] and the PRRSV RFLP 1-7-4 variant used in this study was not characterized beyond an ORF 5 sequence. However, in a previous study,[4] three of the four 1-7-4 isolates caused more severe disease than a known moderately virulent strain. The use of a different PRRSV RFLP 1-7-4 variant, or a completely unrelated variant may have resulted in different outcomes. Therefore, while the results from this experiment support the use of a commercially available PRRS MLV vaccine for the control of PRRS, it should be noted that vaccine efficacy may vary across different variants of PRRSV.

Despite variability among viruses of the PRRSV RFLP 1-7-4 type, this virus type often causes high mortality and morbidity.[1] The time to stability (TTS), defined as time needed to wean PRRSV-negative pigs consistently from a breeding herd after a PRRSV outbreak, was significantly longer for the PRRSV RFLP 1-7-4 type than other PRRSV types.[13] Vaccination of sows and gilts with a PRRS MLV vaccine decreased TTS compared to a combination of sow PRRS MLV vaccination and gilt field virus exposure.[14] This study also reported a numerically lower total loss of pigs per 1000 sows when both sows and gilts were vaccinated relative to other vaccination strategies.

**Table 1:** Least squares means (SEM) for percent mortality and robustness score for vaccinated* and unvaccinated pigs following PRRSV 1-7-4 challenge

| | Vaccinated (n = 100) | Unvaccinated ( n = 98) | *P* value† |
|---|---|---|---|
| Mortality, % | 5.0 (0.03) | 22.4 (0.03) | < .001 |
| Robustness score‡ 7 dpi | 2.59 (0.13) | 3.13 (0.13) | .01 |
| Robustness score‡ 14 dpi | 2.04 (0.15) | 3.25 (0.15) | < .01 |

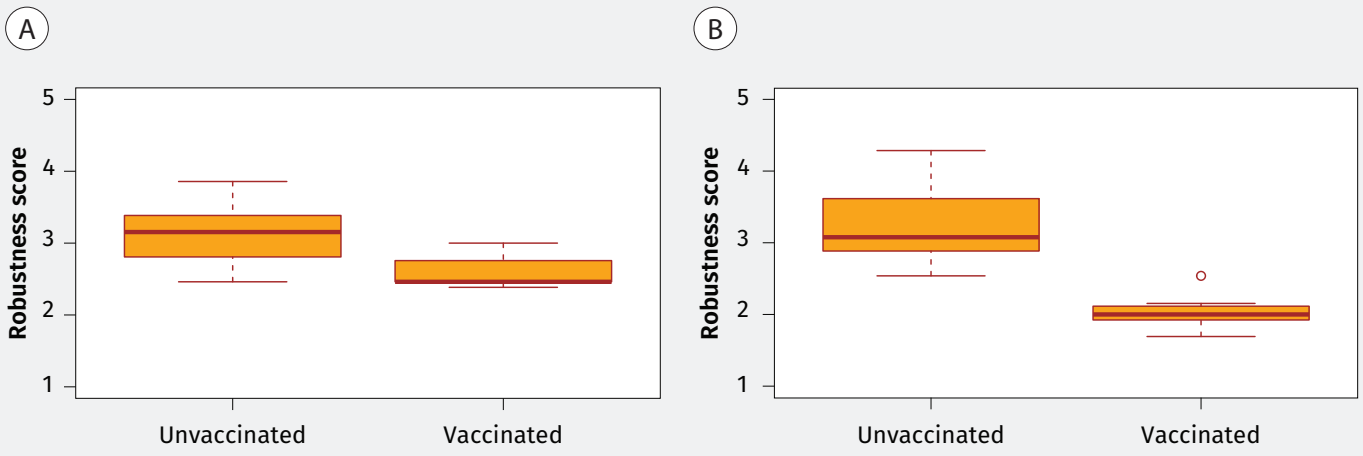
* Ingelvac PRRS ATP, Boehringer Ingelheim.

† The effect of vaccination status (vaccinated for PRRSV, or not) on each response variable using a linear model function.

‡ Robustness score, assigned on a scale from 1 to 5 where 1 = a normal, healthy pig showing no signs of disease and 5 = a candidate for euthanasia.

PRRSV = porcine reproductive and respiratory syndrome virus; dpi = days post infection.

**Figure 1:** Variation in robustness scores at A) 7 and B) 14 days post infection. Pigs were either vaccinated with a porcine reproductive and respiratory syndrome (PRRS) modified live virus vaccine (n = 100) or unvaccinated (n = 98) followed by challenge with PRRS virus lineage 1 isolate 1-7-4. Vaccination status had a significant effect on robustness score at both 7 ($P = .01$) and 14 days post infection ($P < .001$).



Another limitation was the inability to collect growth data from weaning to the end of the study period; however, we could hypothesize that the variation in robustness scores may have been associated with increased variation in body weight post challenge. The study aimed to test differences in mortality and morbidity between pigs vaccinated with a PRRS MLV vaccine and controls. Thus, viremia and immune response data were not collected. The PRRSV RFLP 1-7-4 is diverse and results may not be identical for other PRRSV RFLP 1-7-4 viruses. The PRRSV RFLP 1-7-4 type and a single commercially available PRRS MLV vaccine were tested. Results may not be similar for other virus types and vaccines.

In closing, results from this study demonstrated that vaccination with a PRRS MLV vaccine followed by inoculation with a highly pathogenic PRRSV strain reduced mortality rate and morbidity rate and variation in robustness scores. These results suggest that the use of commercially available PRRS MLV vaccines may be an effective tool to control clinical PRRS in the field.

## Implications

Under the conditions of this study:

- An MLV vaccine reduced mortality and morbidity post PRRSV RFLP 1-7-4 infection.
- The use of commercial PRRS MLV vaccines may assist in controlling PRRS.

## Acknowledgments

The authors thank the South Dakota State University Agricultural Experiment Station, Topigs Norsvin, and Pipestone Applied Research for financial support of this research.

### Conflict of Interest

None reported.

### 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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This fact sheet from the National Pork Board provides key insights into AgView, a Checkoff-funded, opt-in software platform that is free to use for anyone raising pigs.

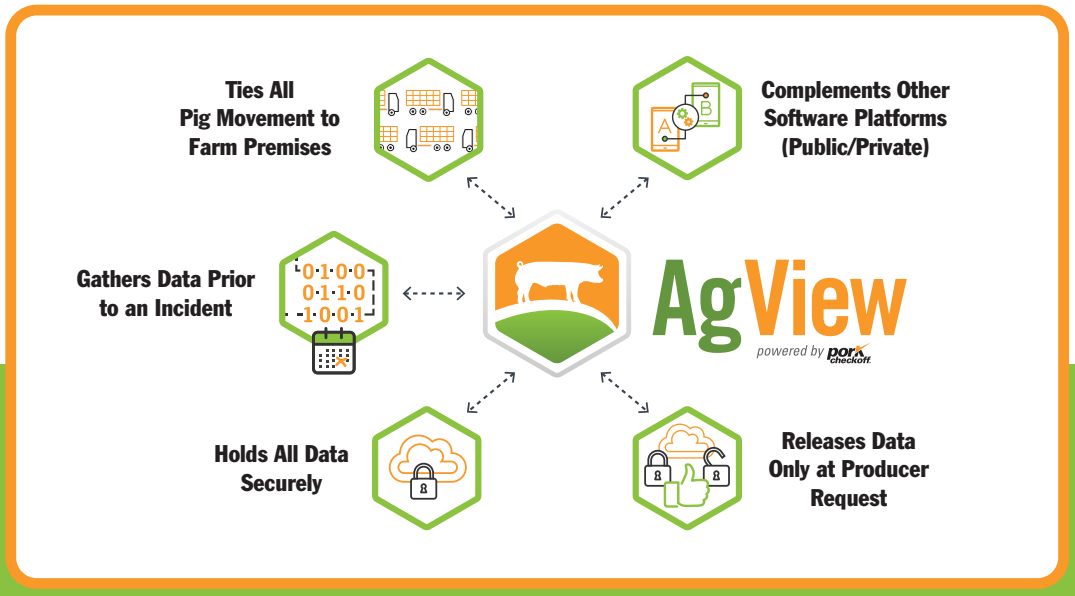
# AgView: A New Tool for a Unified, Real-Time Approach for Foreign Animal Disease Response

A rapid, informed response is vital for quickly containing a foreign animal disease (FAD) outbreak. While reporting protocols are in place on local and state levels, AgView is a free, opt-in technology solution that helps producers provide disease status updates and pig movement data to state animal health officials in real-time. When producers grant permission to share this data, it can be invaluable to creating a faster response to a suspected or confirmed FAD.

## AgView's Value to the Industry

**The AgView platform promotes business continuity for America's pig farmers by uniquely making disease traceback and pig movement data available to the USDA and state animal health officials on Day 1 of a foreign animal disease incident.**

## Important AgView Features




In the event of an African swine fever (ASF) or another FAD outbreak, state veterinarians and other animal health officials will rely on reviewing a massive amount of important data from producers to assist in contact tracing of infected animals/herds. AgView is a permission-based system that is able to rapidly share disease data from producers to animal health officials. Once the data-sharing is approved, AgView can quickly share this vital information, including:

- Where the pigs are and the size and types of farms state vets are dealing with
- Magnitude of animal movement, and more importantly, positive traces
- Lab results from ASF or another FAD
- Compliance with the U.S. Secure Pork Supply plan
- Verification of criteria needed for permitting movement

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|---|---|---|---|

**Q:** A truck holds an average of 1,400 baby pigs. If given a single 200 mg dose of iron 1,109 baby pigs will be subject to iron deficiency anemia. If given a second 200 mg dose, only 427 baby pigs will be subject to iron deficiency anemia, which is an increase of 682 optimal-iron baby pigs. If baby pigs subject to iron deficiency anemia bring $2.77 less at market per head,[1,2,3] how much money is a pork producer leaving on the table with every truckload if they don't use a second dose of Uniferon®?

**A:** $1,889

**Change the math by adding a second dose of Uniferon®.**


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* Industry Standards for Blood Hb Levels (g/L)

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PHARMACOSMOS




PM-060-00

# Highlights: Board of Directors 2021 spring meeting

The AASV Board of Directors met virtually on April 8th to conduct official business. The following are highlights from the meeting:

- The Board welcomed newly elected Vice-President Bill Hollis.
- The Board welcomed newly elected District Directors Megan Inskeep (District 4) and Chris Rademacher (District 6), who began their terms at the conclusion of the board meeting, and Christine Mainquist-Whigham who began her term immediately after election. The Board thanked outgoing District Directors Locke Karriker, Darryl Ragland, and Monte Fuhrman for their service.
- The Board approved the Early Career Committee's funding request of $6376.60 to hold an early career swine veterinarian conference in conjunction with the James D. McKean Swine Disease Conference in November 2021.
- The Board approved funding of up to $10,000 to support Operation Main Street presentations in the remaining 18 US veterinary schools not reached during 2020-2021.
- The Board approved the Student Recruitment Committee's motion for $2500 to support the 2021-2022 series of Swine Medicine Talks: An AASV series for Veterinary Students.
- The Board approved the PRRS Task Force's request to survey AASV members and the broader swine industry regarding PRRS control and elimination.
- The Board established a new award to recognize outstanding contributions from those employed in academia.
- The Board approved name and mission revision requests for the Boar Stud Committee and the Human Health, Safety, and Well-being Committee.
- The Board voted to approve the Influenza Committee's motion to modify the AASV position on influenza A viruses.
- The Board voted to approve the Pig Welfare Committee's motion to modify the AASV position on castration of swine.
- The Board voted to approve the Pig Welfare Committee's motion to modify the AASV position on tail docking and teeth clipping of swine.
- The Board voted to approve the Pig Welfare Committee's motion to reaffirm the AASV position on pig welfare.
- The Board voted to approve the Pig Welfare Committee's motion to reaffirm the AASV position on sow housing.
- The Board voted to approve the Committee on Transboundary and Emerging Diseases' motion to reaffirm the AASV position on permanent identification of swine.
- The Board voted to reaffirm the AASV position on swine health information technology.
- The Board voted to approve the Committee on Transboundary and Emerging Diseases' motion to establish the AASV position on the risk of foreign animal disease introduction through feed and feed ingredients.

Read all AASV position statements at **aasv.org/aasv/positions**. View each committee's plan of work at **aasv.org/aasv/committee**. AASV members can read complete Board and Executive Committee meeting minutes at **aasv.org/aasv/board**.

# Student Recruitment Committee volunteers host virtual booth at SAVMA Symposium

The AASV sponsored a booth at the 2021 virtual symposium of the Student American Veterinary Medical Association (SAVMA) March 13th through 15th. The AASV Student Recruitment Committee member volunteers Drs Corinne Bromfield, Jessica Seate, and Jenna Scott staffed the booth to answer questions and share AASV student membership benefits with the approximate 1700 SAVMA Symposium attendees. Most students who asked questions were curious if AASV student membership was beneficial to students unsure of their interest in swine. The answer was a resounding, "Yes!" They further explained that AASV student membership provides students resources and professional connections to explore their potential interest in swine. Additionally, swine medicine and production medicine skills are applicable to many other specialties and areas of veterinary medicine.

*AASV news continued on page 213*

# Introducing

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Phibro is implementing the use of EASE technology to grow bacteria such as *Salmonella spp.*, *E. coli* and other Gram-negative organisms for production of autogenous vaccines.

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*Potency and efficacy of autogenous biologics have not been established.
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*AASV news continued from page 211*

# Swine Medicine Talks: An AASV video series for students

The Swine Medicine Talks are a 3-part swine medicine seminar series, hosted by the Iowa State University AASV student chapter and funded by the AASV Student Recruitment Committee since 2016. The free series is currently available by live audio/video stream to other veterinary schools across North America and to AASV members. The recordings of previous Swine Medicine Talks have been added to the AASV Video Library and are available for members to view at **aasv.org/members/only/video/smecast.** Recent topics have included economics of swine marketing, genetically engineered swine for disease resistance, and a recent graduate panel.

# Committee on Diversity, Equity, and Inclusion established by AASV Board of Directors

The AASV Board of Directors established a Diversity, Equity, and Inclusion Committee during their spring 2021 meeting. The proposed committee mission statement is:

Create a socially conscious organizational culture that removes barriers to diversity, equity, and inclusion. Make recommendations that result in a comprehensive effort to enhance diversity, equity, and inclusion within the organization through actionable goals with defined timelines. Increase diversity, equity, and inclusion awareness through member education.

Interested in joining the committee? Contact Dr Abbey Canon, Director of Public Health and Communications, at **canon@aasv.org**.

# Call for abstracts – Industrial Partners sessions

The American Association of Swine Veterinarians invites submissions for the Industrial Partners oral and poster sessions at the 53rd AASV Annual Meeting. This is an opportunity for commercial companies to make brief presentations of a technical, educational nature to members of the AASV. The conference will be held February 26 through March 1, 2022 in Indianapolis, Indiana.

The oral sessions consist of a series of 15-minute presentations scheduled from 1 to 5 PM on Sunday afternoon, February 27th. A poster session takes place the same day. Poster authors will be required to be stationed with their poster from noon until 1 PM, and the posters will remain on display throughout the afternoon and the following day for viewing.

**SUBMISSION PREREQUISITE:** All companies submitting topics for presentation during the Industrial Partners sessions must register to participate in the AASV Technical Tables Exhibit before October 1st.

Restricted program space necessitates a limit on the number of presentations per company. Companies that are a member of the *Journal of Swine Health & Production* Industry Support Council **and** sponsor the AASV e-Letter may submit three topics for oral presentation. Companies that are **either** a member of the JSHAP Industry Support Council **or** sponsor the AASV e-Letter may submit up to two topics. All other companies may submit one topic for oral presentation. In addition, every company may submit one topic for poster presentation, but the topic must not duplicate the oral presentation. All topics must represent information not previously presented at the AASV Annual Meeting or published in the meeting proceedings.

**To participate, send the following information to aasv@aasv.org by October 1, 2021:**
1) Company name
2) Presentation title
3) Brief description of the presentation content
4) Presenter name and contact details (mailing address, telephone number, and email address)
5) Whether the submission is intended for oral or poster presentation

Receipt of submissions will be confirmed by email. Presenters will be notified of their acceptance by October 15th and must submit a paper by November 12th for publication in the meeting proceedings. Failure to submit the paper in a timely manner will jeopardize the company's future participation in these sessions.

**The presenting author is required to register for and attend the meeting in person to make the presentation**. Recorded or virtual presentations will not be accepted unless the meeting converts to an entirely virtual event.

Presenters may register for the meeting either as a Tech Table representative, or as an individual registrant (nonmember oral and poster presenters are eligible to register at the AASV regular member rate). AASV does not provide a speaking stipend or travel reimbursement to Industrial Partners presenters.

*AASV news continued on page 215*

## 2022 Annual Meeting

The AASV is moving forward with plans to hold the 2022 AASV Annual Meeting on-site in Indianapolis on February 26 – March 1. Check **aasv.org/annmtg** for updated information and revisions.


## Build a productive herd with a healthy gut.

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*AASV news continued from page 213*

# Call for abstracts – Student Seminar

The American Association of Swine Veterinarians announces an opportunity for veterinary students to make a scientific presentation at the AASV Annual Meeting in Indianapolis, Indiana, on Sunday, February 27, 2022. 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 (2021-2022) student member of the AASV at the time of submission and must not have graduated from veterinary school prior to February 27, 2022. Submissions are limited to 1 abstract per student.

## Abstract submission

Microsoft Conference Management Toolkit will be used to receive and review student abstract submissions. Abstracts and supporting information must be submitted online at **https://cmt3.research.microsoft.com/AASV2022.** Submissions must be completed before **11:59 PM Central Daylight Time** on **Wednesday, September 15, 2021** (firm deadline). Late submissions will not be considered.

Students will receive an email confirmation of their submission. If they do not receive the confirmation email, they must contact Dr Andrew Bowman (**bowman.214@osu.edu**) by Friday, September 17, 2021 with supporting evidence that the submission was made in time; otherwise the abstract 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 of the review results by October 15, 2021, and those selected to participate will be expected to provide the complete paper or abstract, reformatted for publication in the conference proceedings, by November 12th.

## Student Seminar and Scholarships

As sponsor of the Student Seminar, **Zoetis** provides a total of $20,000 to fund awards and the top student presenter scholarship. The student presenter of each paper selected for ORAL presentation receives a $750 award when they make the presentation at the meeting. These students also compete for one of several scholarships awarded through the AASV Foundation. The oral presentations will be judged to determine the amount of the scholarship awarded. **Zoetis** funds a $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 scholarships of $2500 each for 2nd through 5th place, $1500 each for 6th through 10th place, and $500 each for 11th through 15th place.

## Student Poster Session

Abstracts that are not selected for oral presentation in the Student Seminar will be considered for presentation in a poster session at the annual meeting. **Zoetis**, sponsor of the Student Poster Session, has joined with AASV to provide a $250 award for each student poster presenter at the meeting. Students selected to make a poster presentation will be expected to supply a brief paper, formatted for publication in the conference proceedings, by November 12th. The guidelines for preparing posters for the display are available at **aasv.org/annmtg/2022/posters.php**.

## Veterinary Student Poster Competition

The presenters of the top 15 poster abstracts compete for scholarship awards ranging from $200 to $500 in the Veterinary Student Poster Competition, sponsored by **United Animal Health**. See **aasv.org/annmtg/2022/postercomp.htm** for poster judging details.

In all cases, the student presenter is required to attend the meeting in person to make the presentation. Recorded or virtual presentations will not be accepted unless the meeting converts to an entirely virtual event.

Complete information for preparing and submitting abstracts is available at **aasv.org/annmtg/2022/studentseminar.htm**. The rules for submission should be followed carefully. For more information, contact the AASV office by phone, 515-465-5255, or email, **aasv@aasv.org**.

# Call for abstracts – Research Topics session

Plans are underway for the 53rd Annual Meeting of the American Association of Swine Veterinarians (AASV), to take place February 26 through March 1, 2022 in Indianapolis, Indiana. As part of the meeting, there will be a session highlighting research projects related to swine health and production. Abstracts are now being accepted to be considered for presentation during the Research Topics session, which will be held Sunday, February 27.

Those interested in making a 15-minute oral presentation should submit a 1-page abstract on applied research related to swine health and production issues (virology, bacteriology, parasitology, environment, food safety, odor, welfare, etc) to **aasv@aasv.org** by **August 16, 2021**. Include the presenting author's name, mailing address, phone number, and email address with each submission.

Abstracts not selected for oral presentation will be considered for poster presentation. All submitting authors will be notified of the selection results in September. Authors of abstracts selected for oral or poster presentation must provide a paper, formatted for publication in the conference proceedings, by November 12, 2021.

**PLEASE NOTE:** Participation in the Research Topics oral and poster session is at the presenter's expense. No speaking stipend or travel expense reimbursement is paid by the AASV. **The presenting author is required to register for and attend the meeting in person to make the presentation. Recorded or virtual presentations will not be accepted unless the meeting converts to an entirely virtual event.** Nonmember participants may register at the AASV regular member rate. Qualifying full-time graduate students must join AASV to register at the graduate student member rate.

# AASV Foundation
## *Golf Outing*

Join us

**Wednesday, September 1**

11 AM – 6 PM

## REGISTRATION FORM

☐ **INDIVIDUAL registration - $125.00**
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☐ **TEAM registration - $500.00**
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4. _____

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# Tee up for the Foundation!

It's time to recruit your golf team to support the AASV Foundation! Registration is now open for the annual AASV Foundation Golf Outing, to be held **Wednesday, September 1st** at Veenker Memorial Golf Course in Ames, Iowa. Last year, 56 golfers enjoyed a picture-perfect day on this well-groomed course. While we cannot promise the same weather again this year, there is plenty of room for additional golfers -- so practice your swing and register to spend a relaxing day with your colleagues in support of the foundation.

Members of AASV, industry stakeholders, clients, staff, family, and friends are all invited to register a 4-person team for this fun, 18-hole best-ball tournament. Individual golfers and couples are also welcome and will be assigned to a team. Preregistration is required by August 18th.

Golfer check-in begins at 11:00 AM and a shotgun start at noon kicks off the event. Golfers compete as a foursome against the challenges of the course in addition to participating in individual contests along the way. Using Scrolf electronic scoring, golfers can check their progress against the other teams as they make their way around the course.

Contests and giveaways offered by sponsors at the golf holes add to the fun - and prizes! This year's golf hole sponsors include **AgCreate Solutions, Aurora Pharmaceutical, Chr Hansen, GVL, Huvepharma, Insight Wealth Group, Kemin Animal Nutrition & Health, LeeO, Merck Animal Health, National Pork Producers Council, Pharmgate Animal Health, Phibro Animal Health, Ralco, and Topigs Norsvin USA**.

**APC** supplies boxed lunches and **Zoetis** keeps golfers well hydrated with beverages throughout the afternoon. At the conclusion of the golfing, event coordinator Dr Josh Ellingson announces the team and individual contest winners during the pork dinner sponsored by **Boehringer Ingelheim Animal Health**.

The registration fee ($125 per golfer or $500 per team) includes 18 holes of best-ball golf, cart, lunch, beverages, awards dinner, and prizes. Funds raised by the event support AASV Foundation programs, including research grants, travel stipends for students attending the AASV Annual Meeting, swine externship grants, scholarships for veterinarians pursuing board certification in the American College of Animal Welfare, student debt relief scholarships, AASV member heritage videos, and more.

For a sneak peek at the golf course, visit **veenkergolf.com.** For more information or to register, see **aasv.org/foundation/golf**, or contact AASV by phone, 515-465-5255, or email, **aasv@aasv.org**.

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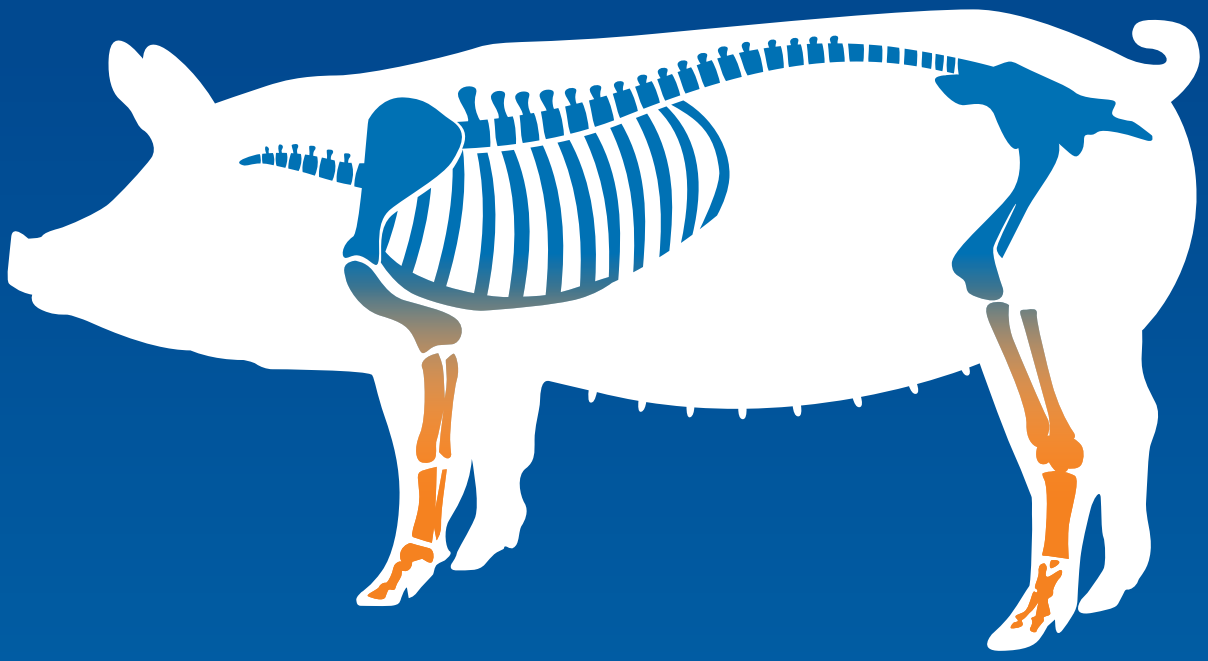

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# Empowering you to advocate

Perpetually linked on the AASV website homepage is an article written by Dr Snelson in 2012. In that article, he poses the question, "Who advocates for swine veterinarians?"[1] Spoiler alert: it's you!

Like it or not, being a swine veterinarian means being an advocate. Sometimes you are an advocate for agriculture, sometimes for public health, hopefully often for yourself, but you are always an advocate for the pig.

Advocacy might be needed in many spaces. Perhaps in the classroom with students curious or concerned how pigs are raised. Occasionally with our barnyard colleagues. Certainly with legislators, regulators, and any other decision makers in policy development and implementation. Often with influencers who may drive consumer perceptions and policy makers. And as we have recently experienced, even within our own veterinary profession.

No matter where, when, or why the need for advocacy arises, we can be sure that if we do not advocate for ourselves, no one else will. In our small profession, we have an obligation and an opportunity to share our expertise developed from our unique experiences as swine veterinarians. No one else can describe how a proposed change will impact your daily life. In our absence, however, someone else who may have a different motive will speak for us. We want decision makers to hear about animal health, animal welfare, and veterinary practice from you. Now, I hope you feel empowered to start advocating.

**First, stay informed.** Watch the e-Letter for announcements about proposed rulemaking. Listen to webinars hosted by the American Veterinary Medical Association (AVMA) or AASV. Observe regulatory agency public forums describing proposed policy changes. Review AASV committee reports. Read trade publications for situational awareness of issues the industry is facing. Subscribe to the AVMA Congressional Advocacy Network to monitor decisions that impact veterinarians, animal health, animal welfare, and public health.[2]

By staying informed, something might pique your interest, or you might learn about something that could have a significant impact on the way you practice veterinary medicine.

**Next, get involved!** Participate in an AASV committee. The AASV Board of Directors establishes committees to address specific issues associated with swine veterinary medicine and provide recommendations for actions to the AASV leadership. A list of committees can be found at **aasv.org/aasv/committee**. Almost all committees need additional members who are swine veterinary practitioners.

Join and maintain membership with AVMA and your state veterinary medication association (VMA) to support swine veterinarians' relevance within those associations. Share your stories and experiences in the veterinary profession. Introduce yourself to your representatives.

*"Your personal story has the most impact."*

Share your comments with AASV staff, leadership, and committees. Let the association speak for and truly represent its members. Your input helps shape AASV's official comments.

**Now, take action.** Volunteer to present Operation Mainstreet presentations in your community or schools. Reach out to colleagues within the veterinary profession to discuss issues. Each allied organization and each state VMA have a representative in the AVMA House of Delegates, listed at **avma.org/about/house-of-delegates-directory**.

Submit your own comments in response to proposed policy. When submitting comments, you can always use AASV drafts as a guide, but personalization is of most importance. Comments from individuals are often more meaningful.

Introduce yourself to your legislative representatives during a non-crisis time. Offer to be a resource in your area of expertise. Remember, you are an expert *and* a constituent – they want to hear from you! Remain nonpartisan and offer science-based information and describe the impact to swine medicine. Consider taking a grass roots approach and offer your representative the opportunity to ride along with you to understand and experience veterinary medicine and swine production.[3]

Might advocacy be your newfound passion? Go big. Participate in the National Pork Producers Council Veterinarian Public Policy Advocacy Program where participating swine veterinarians learn how policy is made on the federal level, about the impact of technical issues on growing international trade, and how to communicate effectively with lawmakers and regulatory officials. Participate in your state veterinary legislative day or the AVMA legislative fly-in that

*Advocacy in action continued on page 221*

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*Advocacy in action continued from page 219*

brings veterinarians to Washington to meet with their members of Congress. Become an AVMA ambassador to directly connect with and build relationships with members of Congress in your state.[2,4]

**Your personal story has the most impact.** Create relationships and make yourself stand out. Describe who you are, who you represent, how this topic affects you, your practice, the animals under your care, the food you help produce, and the clients for whom you work.

Personal experiences often drive policy more than science. Use this as an opportunity. Veterinary medicine is still a respected profession. Each AASV member has an important voice and story, and no one else can share your experience as a swine veterinarian.

If you are still looking for other ways to become more involved, do not hesitate to contact us at 515-465-5255 or **aasv@aasv.org**.

**Abbey Canon, DVM, MPH, DACVPM**
*Director of Public Health and Communications*

## References

*1. Snelson H. Who advocates for swine veterinarians? [editorial]. *J Swine Health Prod*. 2012;20(2):103.

*2. American Veterinary Medical Association. Get Involved. AVMA. Accessed May 2021. **https://www.avma.org/advocacy/get-involved**

*3. American Veterinary Medical Association. Come one, come all: Member power in AVMA advocacy. AVMA Axon. 2020. **https://axon.avma.org/local/catalog/view/product.php?productid=149**

*4. YouTube AVMA Advocacy Playlist. Accessed May 2021. **https://www.youtube.com/playlist?list=PLMszZOQAqfuVrnQr__Uq7NMn_poLBZ3m5**

* Non-refereed references.

*J Swine Health Prod*. 2018;26:215-222.

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# UPCOMING MEETINGS

## Allen D. Leman Swine Conference

September 18 - 21, 2021 (Sat-Tue)|
A hybrid conference
Saint Paul RiverCentre
Saint Paul, Minnesota

For more information:
Email: **vetmedccaps@umn.edu**
Web: **ccaps.umn.edu/allen-d-leman-swine-conference**

## US Animal Health Association 125th Annual Meeting

October 21 - 27, 2021 (Thu-Wed)
Gaylord Rockies Hotel
Denver, Colorado

For more information:
United States Animal Health Association
4221 Mitchell Ave
Saint Joseph, MO 64507
Tel: 816-671-1144
Web: **usaha.org/meetings**

## International Conference on Pig Survivability

October 27 - 28, 2021 (Wed-Thu)
Omaha, Nebraska

For more information:
Dr Joel DeRouchey
Email: **jderouch@ksu.edu**
Web: **piglivability.org/conference**

## ISU James D. McKean Swine Conference

November 4 - 5, 2021 (Thu-Fri)
Scheman Building
Iowa State University
Ames, Iowa

For registration information:
Registration Services
Iowa State University
1601 Golden Aspen Drive #110
Ames, Iowa 50010
Tel: 515-294-6222
Email: **registrations@iastate.edu**

For questions about program content:
Dr Chris Rademacher
Conference Chair
Iowa State University
Email: **cjrdvm@iastate.edu**

## AASV Early Career Conference

November 5, 2021 (Fri)
Scheman Building
Iowa State University
Ames, Iowa

For more information:
Email: **aasv@aasv.org**

## American Association of Swine Veterinarians 53rd Annual Meeting

February 26 - March 1, 2022 (Sat-Tue)
JW Marriott Indianapolis
Indianapolis, Indiana USA

For more information:
American Association of Swine Veterinarians
830 26th Street
Perry, Iowa 50220 USA
Tel: 515-465-5255
Email: **aasv@aasv.org**
Web: **aasv.org/annmtg**

## 26th International Pig Veterinary Society Congress

June 2022 - Date to be determined
Rio de Janeiro, Brazil

For more information:
Tel: +55 31 3360 3663
Email: **ipvs2020@ipvs2020.com**
Web: **ipvs2020.com**

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

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