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*The Journal of the American Association of Swine Veterinarians*

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SWINE VETERINARIANS

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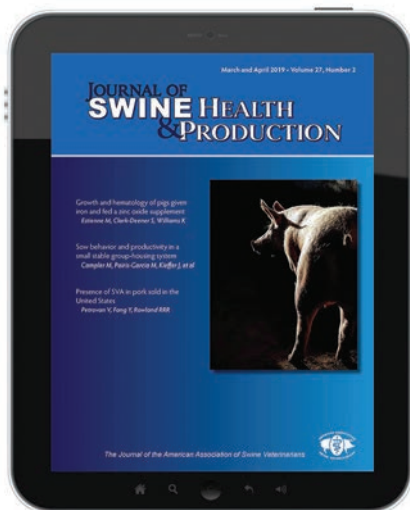
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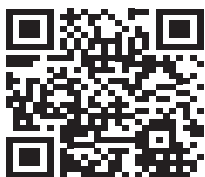
## About the cover…

Pig from farm in Mexico.

*Photo courtesy of Maria De Lourdes Soto*

*Submitted by Dr Victor Quintero Ramirez, from Mexico City*

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"I ask you to ponder: What is on your professional bucket list to do, accomplish, or visit before you retire?"

*quoted from the Executive Editor's message, page 63*

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# Why A Higher Standard Is Worth Its Weight

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[1] Radke, S.L., Olsen, C.W., Ensley, S.M., (2018) Elemental impurities in injectable iron products for swine. *The Journal of Swine Health and Production*, 26(3).

[2] Gaddy H et al. A review of recent supplemental iron industry practices and current usage of Uniferon® (iron dextran complex injection, 200 mg/mL) in baby pigs. *AASV*. 2012; 167–171.

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# PHARMACOSMOS

# Learning never stops!

I have been extremely blessed to have had good mentors in my life. One thing I have come to realize is that the value of good mentors does not diminish after you get more experience and mentoring does not need to be limited to professional purposes. In addition, I have benefitted from having many great students gain experience in my practice as summer interns or preceptors. It has been an opportunity for me to pay it forward in a small way. In this journal issue, I am going to take some time to discuss the features and benefits of a productive mentor-mentee relationship.

Whether you are looking for a mentor or providing mentoring, it's important to know what qualities are important. What are the features of good mentors?

- Good mentors willingly share knowledge, skills, and expertise. Quality mentors understand where mentees are in their development and tailor input to meet their needs at the time. They can relate to the mentee through shared experiences.
- They have a personal interest in the mentoring relationship. The responsibility to provide effective training or teaching is not taken lightly. A mentor's personal interest translates into a commitment to the mentee to help them become more successful.
- Good mentors have positive attitudes and are role models in their area of expertise. Their enthusiasm is contagious and helps the mentee feel like their purpose has meaning. They are respected across different organizations and within their own organization.
- Ongoing learning and growth are important to good mentors. Even after excelling in an area, there are always new things to learn. Openness to experimentation and learning new practices demonstrate to mentees that the time they spend learning will be rewarded.
- Effective mentoring requires guidance and constructive feedback. Helping mentees build on strengths and identify weaknesses is imperative in a successful mentoring relationship.
- Effective mentors demonstrate the ability to set and meet their own personal and professional goals. By setting a good example, they help motivate others.
- Great mentors value the perspectives of others and their initiative. Encouragement helps mentees focus and provides the positive reinforcement for growth and development.

As a mentee, what can you do to maximize the value of a mentoring relationship?

- Be committed to learning and growing. Don't be a consumer of education and experience. Be an active participant and help create opportunities to learn. Take initiative to meet your goals.
- Respect your mentor. They are giving their time and resources to you, be gracious.
- Have realistic and clear goals for the relationship. I've been surprised at times how the benefits of a good mentoring relationship may not be immediate. Great mentoring creates value over time and in situations you may least expect it.

*"Whether you are looking for a mentor or providing mentoring, it's important to know what qualities are important."*

- Be open to feedback. Mentors who are genuinely interested in your success will be honest and frank with you about areas where you can improve. Take their feedback to heart and work on those areas without being too critical of yourself. No one is perfect!
- Don't be afraid to disagree. I never learned anything from someone who agreed with me. Understanding differences in perspectives is an inherent part of the learning process.
- Ask lots of questions. Well thought out questions demonstrate sincere interest and commitment to improvement. A good question is appreciated and helps a mentor gauge knowledge and tailor experiences and input to the mentee.

This is my last president's message and I want to thank all of you for the opportunity to serve in this role. It has been an honor and a privilege. An organization is only as good as its members and staff, and we have great people contributing in countless ways. Thank you for all that you do for the American Association of Swine Veterinarians. I am extremely thankful for all your efforts and contributions to our organization. Best of luck to you in the future, I wish you all success!

C. Scanlon Daniels, DVM
AASV President

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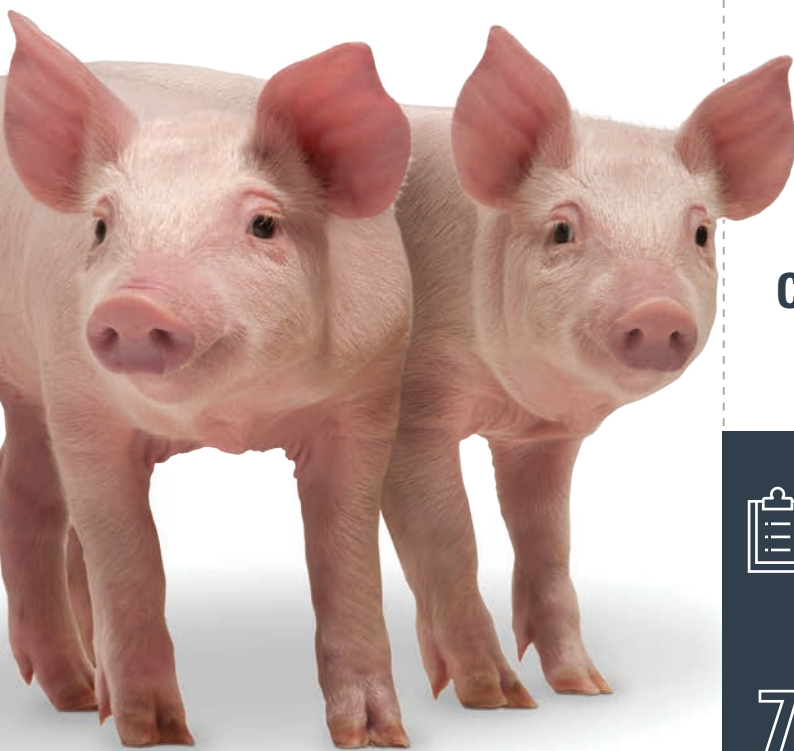
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# Be proud of who we (you) are

I'm sitting in front of the fireplace on New Year's Day, watching the deer outside our window in over 2 ft of fresh snow, and writing my president-elect message for the March and April issue of the *Journal of Swine Health and Production*. This is not because I've resolved to extinguish the "procrastiNATE" moniker I have rightfully earned over the years, but rather I hope to start the year on the right foot with the editors of JSHAP and submit my article on time.

## Built to last

I look forward to my tenure as AASV president and am very grateful for the opportunity. You will receive this JSHAP issue just prior to our annual meeting, which is themed *Built to Last: Celebrating 50 Years of Progress*. To really understand the origin of the *Built to Last* theme and why the AASV has had lasting success now and into the future, I strongly encourage you to read Dr John Waddell's proceedings paper, "Built to Last: 50 Years of AASV."[1] It is a thorough history of our heritage as a professional organization and it will really make you proud to be a part of this great organization.

Here are some key messages from Dr Waddell's presentation:

- From the original idea of creating an association specific to swine with the mission to increase the level of expertise and knowledge of pig veterinarians, a handful of forward-thinking veterinarians grew that idea into a world class organization. This organization and its members, through a common uniting cause, changed the trajectory of the global swine industry.

- When challenged with lice, mange, classical swine fever, pseudorabies, porcine reproductive and respiratory syndrome, porcine circovirus associated disease, influenza A virus, and porcine epidemic diarrhea, swine veterinarians have been instrumental in finding solutions for control and elimination. Strategies like Specific Pathogen Free stock, depopulation strategies, multi-site production, air filtration, load-close-expose, wean down, and management changes to reduce exposure to bacteria and eliminate losses, all had their roots with swine veterinarians.

- "Once a swine vet, always a swine vet!" We are all part of a family connected by a common idea, cause, and a reason for existing: the pig. We help feed the world while caring for, respecting, and doing what is right for the pig. It is not just a job, it is a commitment.

- "See one, do one, teach one!" Believing in what you do every day and helping others do the same is a brilliant long-term strategy. Caring is the essential emotion that binds our clan together.

Dr Waddell obviously cares a lot! He really paid it forward with an excellent proceedings paper and was the right choice to present this prestigious Howard Dunne lecture.

## What do we stand for? What is our role?

Dr Waddell's comments on feeding the world remind me of a video clip titled "What is the Ethical Choice for People, Animals and Planet?"[2] that I sometimes use at the beginning of my Operation Main Street (OMS) presentations. It depicts the analogy of an apple as the earth. The apple is sliced to demonstrate the earth's scarce land and water resources showing that only 1/32 of the land is available for growing crops and less than one-half of 1% of water is available for human use. Global population growth is adding more than 200,000 people per day and may reach 9 billion by 2050, which could require almost twice as much food produced than in 2010! The video ends with the question, "What's the right choice for people, animals, and the planet?"

As swine veterinarians our ultimate role, challenge, and opportunity is to do our part to help feed the world more efficiently and sustainably. The Pork Checkoff funded OMS program is another avenue for us to present information about how the swine industry has changed in the last 50 years with dramatic improvements in production and reproduction efficiency, while keeping the pig's welfare and environmental sustainability top of mind. Operation Main Street is an opportunity to educate the public on the swine industry and to inform people of our role in society. It's a good way to promote animal agriculture with both our personal stories and scientific facts and feel good about what swine veterinarians are doing.

Thanks to all those AASV members already involved in OMS. To date, the program has 132 OMS-trained veterinarians who have presented more than 300 OMS speeches to over 15,500 people, including presentations at all 30 US veterinary medicine schools. If you haven't tried it, please do, as I think you will enjoy it.

## Epilogue

The sun has long since set, I can no longer identify the deer outside the window, and I have just completed my first message. Wishing you the very best this year, enjoy the meeting, and be proud of who we (you) are. Thank you, and good night.

Nathan Winkelman, DVM
AASV President-elect

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# Last time

This is my last message as executive director of the AASV. One of many "lasts" I have been experiencing since my decision to step down. I have pondered over this message and I realize that there is so much to say that I cannot possibly cram it all into the 800 words allowed on this page. Instead, I will leave you with three simple statements: *believe, count your blessings,* and *give thanks.*

Early in my career with the AASV, I came to realize that its members really believe in the organization. It comes down to more than just weighing the cost-to-benefit equation of paying dues. Members believe in the mission of the AASV. They believe that there is value to belonging to an organization that will increase their knowledge while also representing them on multiple levels, in diverse settings, and on subjects that are important. They believe that an organization is stronger than any one individual because of member input, participation, and leadership. The AASV has often been described as a family by outsiders attending our annual meeting. I think this speaks very well of the common characteristics shared by our members, including the beliefs that swine veterinarians do important work, that pigs and people

are the reason we do what we do, and that relationships are vital to both personal and professional life.

I have been blessed to have been a member of the AASV family for 40 years, beginning as a veterinary student, then practitioner, and then as an employee. The blessing of knowledge from AASP was invaluable at the beginning of my career as a young practitioner. As I grew more experienced, however, the value of knowledge never diminished as new challenges in practice arose and as the pork industry evolved. Despite changes in the industry, an important fact remains today: pigs need veterinarians. If that remains true, and I believe it will, then veterinarians will always need to increase their knowledge.

As an employee of AASV, I have been blessed in several ways. Early in my time with AASP I experienced the blessing of insightful and bold volunteer leadership as the AASP officers and board of directors chose to establish a stand-alone office with full-time staff. After the 2019 Annual Meeting, I will have had the blessing of serving under 26 presidents and more district directors than I can count. Each contributed their time and talents to the organization while expecting nothing in return. Each decision made by the leadership was made with thoughtful consideration. As an association executive, I could ask for nothing more than that.

I have been blessed with working alongside skilled and committed coworkers. Over the years I have had to do little in terms of human resource management, other than ensure that each person had the resources needed for the job and then to stay out of their way. The AASV would not be the organization it is today without the hard work and dedication of every staff person. I could not have asked for better people to work alongside. The AASV will do well to continue to give them the same type of support and appreciation given me during my tenure.

> *"I will leave you with three simple statements:* **believe, count your blessings,** *and* **give thanks."**

A pastor at my church once asked an elderly lady this question: "If given the opportunity at the time of your death, you could leave your kids some words of wisdom, what would they be?" She replied with no hesitation, "Give thanks!" Two simple words but still a powerful message.

Thank you to each and every member of AASV over the years! Thanks for your support and kind words! It has been a distinct honor and pleasure to work for you. Thank you to those members who were a pain in the ass! You know who you are, but do not worry because I benefited more from the challenges and swift kicks than I would have from soft treatment.

Thank you to the leadership of AASV! Each of you was accountable for your position and treated it with respect and appreciation. You had my back during my time at AASV. You never second-guessed or micro-managed my decisions or my work. There was never a single day in the last 25 years when I regretted working for you. For an association executive, that's rare.

Thank you to my staff at AASV! I am in awe of your professionalism, talents, intellect, humor, dedication, and hard work. There is no way I could have done my job to the best of my ability without each one of you. To put it simply, you are the best!

Finally, thank you to my wife, Sue Kimpston, and my kids, Kay and Joey! Your love, your care, and your presence make my life complete.

That's it! Last time! Take care and God bless!

Tom Burkgren, DVM
Executive Director
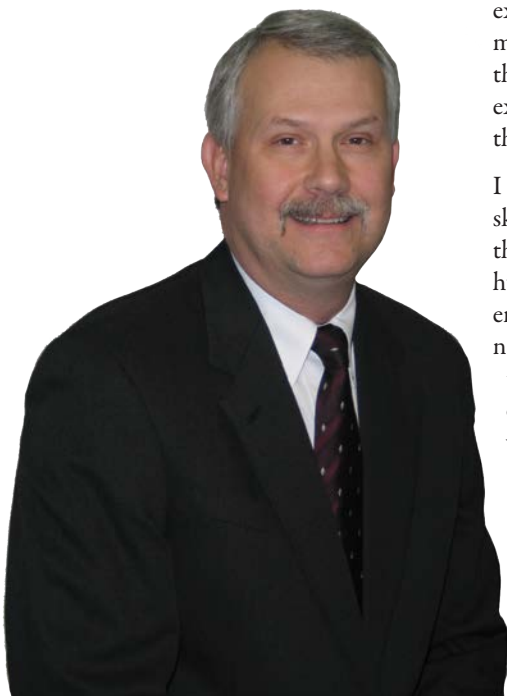
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# Bucket list

I am starting to notice that a trend has firmly developed when it comes time for me to write my message. I am again sitting in an airport on my way home from a pig-focused conference. This time the conference was in Banff, Alberta, Canada. Many conference attendees mentioned that Banff has been on their bucket list for years. If you have not been, you must put it on your bucket list too because, *wow*, what a beautiful place to visit. I felt like I was inside a gloriously beautiful and magical snow-globe for a week, and the conference was also fantastic. For those of you who are too young to know what a snow-globe is – ask Siri!

I started thinking about what is on my bucket list and, as usual, I pondered – where did the expression "bucket list" originate? Turns out, one mainstream source of the term was the 2007 movie *The Bucket List* starring Jack Nicholson and Morgan Freeman. I have not seen it, but the plot follows the two main characters who are terminally ill on their journey to check-off items on their to-do wish list (ie, bucket list) before they die. Sounds like a sad movie so I will pass on seeing it for now. Even so, the term bucket list seems to be a common colloquial term used at coffee breaks, around the water cooler at the office, and as a conversation starter at many social gatherings. Under these circumstances, it is a more light-hearted topic.

What is on my bucket list? Contribute to world peace? Write a book? Travel to Antarctica? Complete an Ironman? I realized I don't really have a personal bucket list, but these items seem like a challenge and subject to change. Whereas thinking with my pig-vet hat on, I do have some professional bucket list items: contribute to feeding the world safe and nutritious animal protein; visit other countries to learn about their swine production systems and animal health strategies, although perhaps not Antarctica; and visit other universities to learn and understand the challenges they face and strategies they use to train veterinarians. This list was much easier to come up with because it is what I strive to do every day. If you were to only read my messages, you may think I was always traveling to a conference, whittling away at my bucket list. In reality, I will have the opportunity in the not too distant future to take a sabbatical with the primary purpose being professional development. As veterinarians, we are all familiar with professional development and continuing education. Therefore, I am working on refining my bucket list items for my professional development and sabbatical time.

> *"As veterinarians, we are all familiar with professional development and continuing education."*

One item I had on my list years ago, before I even knew what a bucket list was, was to return to university to complete a graduate degree in epidemiology. It was something I always knew I wanted to do. I graduated with my DVM many moons ago and, as time went by, the thought of returning to school seemed more and more impossible, yet I did it. After 15 years of clinical practice I can say that the experience of returning to do graduate work was rewarding and helped me to land where I am today. If you are thinking you cannot teach an old dog new tricks, think again. Take that MBA course, pursue swine health management board certification, buy into your practice, or add to your professional development bucket list. I ask you to ponder: What is on your professional bucket list to do, accomplish, or visit before you retire?

Terri O'Sullivan, DVM, PhD
Executive Editor

# Growth performance and hematology characteristics in pigs treated with iron at birth and weaning and fed a nursery diet supplemented with a pharmacological level of zinc oxide

Mark J. Estienne, PhD; Sherrie G. Clark-Deener, DVM, PhD; Kimberly A. Williams, BS

## Summary

**Objective:** To determine effects of an iron dose at weaning on growth and hematology in pigs fed zinc.

**Materials and methods:** Weaned pigs (n = 144) were allocated to treatments in a 2 × 2 × 2 factorial arrangement (6 pens/treatment, 3 pigs/pen), with factors being pig size (large or small); number of 100 mg iron dextran doses (1 [birth] or 2 [birth and weaning]); and dietary zinc (100 or 2000 ppm). Average daily gain (ADG), feed intake (ADFI), and gain to feed ratio (G:F) were determined. Blood samples were collected at weaning and 7 and 49 days post-weaning.

**Results:** Anemia (hemoglobin < 9.0 g/dL) at weaning tended to be greater ($P$ = .07) for large pigs and hemoglobin ($P$ = .02) and hematocrit ($P$ = .05) were greater in small pigs. Hematology was largely unaffected by number of iron doses or diet. Large pigs displayed greater ADG ($P$ < .001) but poorer G:F ($P$ = .002). Zinc-supplemented pigs had greater ($P$ = .002) ADG and G:F from day 0 to 21. From day 22 to 49, G:F ($P$ = .005) was greater for controls. Overall, zinc tended to increase ADFI in large ($P$ = .09) but not small ($P$ = .46) pigs. Growth was largely unaffected by number of iron doses.

**Implications:** Anemia at weaning was common, especially for larger pigs, but was not exacerbated by zinc. An iron dose at weaning had minimal effects on growth. Dietary zinc enhanced growth early post-weaning but effects waned as pigs aged.

**Keywords:** swine, nursery, iron, zinc, hematology

## Resumen – Desempeño del crecimiento y características hematológicas en cerdos tratados con hierro al nacer, al destete y alimentados con una dieta de destete suplementada con un nivel farmacológico de óxido de zinc

**Objetivo:** Determinar los efectos de una dosis de hierro al destete en el crecimiento y hematología en cerdos alimentados con zinc.

**Materiales y métodos:** Cerdos al destete (n = 144) fueron distribuidos en tratamientos en un arreglo factorial de 2 × 2 × 2 (6 corrales/tratamiento, 3 cerdos/corral), siendo los factores tamaño del cerdo (grande o chico); número de dosis de 100 mg de hierro dextran (1 [nacimiento] o 2 [nacimiento y destete]); y zinc dietético (100 o 2000 ppm). Se determinaron la ganancia diaria promedio (ADG por sus siglas en inglés), consumo de alimento (ADFI por sus siglas en inglés), y relación ganancia alimento (G:F por sus siglas en inglés). Se tomaron muestras de sangre al destete y a los 7 y 49 días post destete.

**Resultados:** La anemia (hemoglobina < 9.0 g/dL) al destete tendió a ser mayor ($P$ = .07) en los cerdos grandes y la hemoglobina ($P$ = .02) y los hematocritos ($P$ = .05) fueron mayores en cerdos pequeños. La hematología en su mayor parte no se vio afectada por el número de dosis de hierro o dieta. Los cerdos grandes tuvieron una mayor ADG ($P$ < .001) pero una menor G:F ($P$ = .002). Los cerdos suplementados con zinc tuvieron mayor ($P$ = .002) ADG y G:F del día 0 al día 21. Del día 22 al 49, la G:F ($P$ = .005) fue mayor en los controles. En general, el zinc tendió a incrementar el ADFI en cerdos grandes ($P$ = .09) pero no en pequeños ($P$ = .46). El crecimiento en general no se vio afectado por el número de dosis de hierro

**Implicaciones:** La anemia al destete fue común, especialmente en los cerdos grandes, pero no se agravó por el zinc. Una dosis de hierro al destete tuvo efectos mínimos en el crecimiento. El zinc dietético mejoró el crecimiento al inicio del destete pero los efectos decrecieron al avanzar la edad de los cerdos.

MJE, KAW: Virginia Tech-Tidewater Agricultural Research and Extension Center, Suffolk, Virginia.

SGC-D: Virginia-Maryland College of Veterinary Medicine, Blacksburg, Virginia.

**Corresponding author**: Dr Mark J. Estienne, Virginia Tech-Tidewater Agricultural Research and Extension Center, 6321 Holland Road, Suffolk, VA 23437; Tel: 757-807-6551; Fax: 757-657-9333; Email: mestienn@vt.edu.

This article is available online at http://www.aasv.org/shap.html.

## Résumé – Performances de croissance et caractéristiques hématologiques chez des porcs traités avec du fer à la naissance et au sevrage et nourris avec un aliment en pouponnière supplémenté avec une quantité pharmacologique d'oxide de zinc

**Objectif:** Déterminer les effets d'une dose de fer au sevrage sur la croissance et des données hématologiques chez des porcs nourris avec du zinc.

**Matériels et méthodes:** Des porcs sevrés (n = 144) ont été répartis à des traitements dans un arrangement factoriel (6 enclos/traitement, 3 porcs/enclos), avec les facteurs étant la taille des porcs (gros ou petit); le nombre de doses de 100 mg de fer dextran (1 [naissance] ou 2 [naissance et sevrage]); et quantité de zinc alimentaire (100 ou 2000 ppm). Le gain moyen quotidien (ADG), la quantité de nourriture consommée (ADFI) et le ratio gain/aliment consommé (G:F) ont été déterminés. Des échantillons sanguins étaient obtenus au sevrage et 7 et 49 jours post-sevrage.

**Résultats:** De l'anémie (hémoglobine < 9.0 g/dL) au moment du sevrage avait tendance à être plus importante (*P* = .07) pour les gros porcs et l'hémoglobine (*P* = .02) et l'hématocrite (*P* = .05) étaient plus élevés chez les petits porcs. Les valeurs hématologiques étaient dans l'ensemble peu affectées par le nombre de doses de fer ou la diète. Les gros porcs montraient un ADG plus important (*P* < .001) mais un plus faible G:F (*P* = .002). Les porcs supplémentés en zinc avaient un ADG et un G:F (*P* = .002) plus élevés du jour 0 au jour 21. Du jour 22 au jour 49, le G:F était plus élevé pour les animaux témoins (*P* = .005). De manière globale, le zinc avait tendance à augmenter l'ADFI chez les gros (*P* = .09) mais pas les petits (*P* = .46) porcs. La croissance était largement non-affectée par le nombre de doses de fer.

**Implications:** L'anémie au moment du sevrage est fréquente, spécialement chez les porcs plus gros, mais n'était pas exacerbée par le zinc. Une dose de fer au moment du sevrage avait des effets minimaux sur la croissance. Le zinc alimentaire augmentait la croissance tôt après le sevrage mais les effets diminuèrent à mesure que les porcs vieillissaient.

I ron deficiency anemia can quickly develop in suckling pigs because the newborn animal has limited capacity for storing iron, sow colostrum and milk have relatively insignificant iron concentrations, and modern genotypes have the capacity for rapid growth rates. To prevent anemia, it is standard industry practice to provide supplemental iron to newborn pigs, usually by administering an intramuscular (IM) injection of 100 to 200 mg iron dextran.[1] Recent research, however, has demonstrated that many pigs, particularly the largest, fastest-growing animals in a litter, are iron deficient or anemic at weaning despite having received supplemental iron during the first week of life.[2,3] After weaning, anemic pigs grow slower than non-anemic counterparts during the nursery phase of production.[3,4] An additional iron dose at weaning could be important, particularly for nursery pigs that consume diets supplemented with pharmacological levels of zinc to enhance growth performance.[5-8] Liver iron concentrations were decreased and anemia developed in pigs consuming diets with high levels of zinc.[9] On commercial farms, elevated concentrations of zinc oxide (approximately 2000 ppm) in nursery diets were associated with a greater risk of anemia in pigs.[3] Thus, the objective of this experiment was to determine the effects of an additional 100 mg iron supplement at weaning on growth performance and hematology characteristics in nursery pigs fed a diet supplemented with 2000 ppm of zinc.

## Materials and methods

The protocol for this experiment was reviewed and approved by the Virginia Tech Institutional Animal Care and Use Committee.

### Study animals and housing

A total of 144 Duroc-sired pigs (74 male and 70 female) farrowed by 18 Yorkshire × Landrace sows were enrolled in this study. Within 24 hours after birth, pigs were ear notched for identification, weighed, and needle teeth were clipped and tails docked. All pigs received an IM injection of 100 mg iron hydrogenated dextran (Iron-100; Durvet, Inc, Blue Springs, Missouri) in the neck muscle behind the ear using a 20 gauge, 1.27 cm-long needle. At 7 days of age, boar pigs were bilaterally castrated using a sterile scalpel. Pigs were not provided creep feed during the suckling period.

Pigs were moved at weaning to an environmentally controlled nursery unit. Pen floors were galvanized steel bar slats. Nursery pens measured 0.91 × 1.22 m[2] and each contained a nipple drinker and stainless steel feeder with four feeding spaces.

### Study design

Pigs were weaned at approximately 21 days of age, weighed, and divided into equal groups of the largest and smallest pigs (average body weight [SE]; 7.91 [0.06] and 5.38 [0.06] kg, respectively). Pigs were housed in groups of 3 pigs/pen in six blocks of eight pens each, with litter of origin and sex balanced across pens. Pens were allocated to a 2 × 2 × 2 factorial arrangement of treatments with 6 replicate pens per treatment combination (total of 48 pens). The factors were: 1) pig size (large or small); 2) number of 100 mg iron dextran IM doses (1 dose administered within 24 hours after birth or 2 doses [one administered within 24 hours after birth and the other at weaning]); and, 3) level of dietary zinc (100 or 2000 ppm).

The amount of iron administered to pigs soon after birth varies in the swine industry with the most common doses ranging from 100 to 200 mg. For this experiment, 100 mg was used because lower doses are less likely to be toxic and to induce oxidative stress. Greater doses of parenteral iron have also been demonstrated to increase liver secretion of hepcidin which perturbs systemic iron metabolic processes.[10,11] Finally, the 100 mg dose given soon after birth would likely increase the number of pigs that were anemic at weaning, allowing for evaluation of how these individuals responded to dietary zinc supplementation.

### Experimental diets

Pigs were allowed *ad libitum* access to a 3-phase feeding regimen with all diets meeting the requirements for the various nutrients[12] and zinc was adjusted as to the concentrations previously indicated. For each phase, a basal diet was first prepared containing most of the corn and all the common ingredients for each experimental diet. Zinc oxide (Maximo 720; Zinc Nacion, Monterrey, Nuevo León, Mexico) or an equal amount of ground corn was then added to the basal diet to create the zinc oxide and control diets, respectively (Table 1).

### Data and sample collection and blood assay

Pigs were weighed at weaning and then weekly for 49 days. Average daily gain (ADG) was determined for the periods of day 0 to 7, day 8 to 21, day 22 to 49, and the entire trial. Feed additions were recorded so that average daily feed intake (ADFI) and the gain to feed ratio (G:F) could be calculated for each period and the entire trial.

Before the second injection of iron was administered to the appropriate pigs, a blood sample was collected from the barrow weighing closest to the average weight of pigs in

**Table 1:** Composition of zinc oxide and control diets fed to nursery pigs for 49 days*

| Dietary phase: | I | II | III |
|---|---|---|---|
| Days fed: | 0 - 7 | 8 – 21 | 22 - 49 |
| **Feed component, %** | | | |
| Ground corn | 41.95 | 54.76 | 64.76 |
| Soybean oil | 3.00 | 3.00 | 3.00 |
| Dried whey | 25.00 | 10.00 | 0.00 |
| Menhaden fish meal | 4.00 | 2.00 | 0.00 |
| Soycomil† | 3.00 | 2.00 | 2.00 |
| Soybean meal | 19.85 | 24.90 | 26.65 |
| Dicalcium phosphate | 1.00 | 1.00 | 1.25 |
| Calcium carbonate | 0.70 | 1.00 | 1.00 |
| Salt | 0.20 | 0.20 | 0.20 |
| Lysine-HCL | 0.40 | 0.30 | 0.30 |
| DL-methionine | 0.12 | 0.06 | 0.06 |
| Vitamin-trace mineral‡ | 0.50 | 0.50 | 0.50 |
| Zinc Oxide or ground corn | 0.28 | 0.28 | 0.28 |
| **Totals** | **100.00** | **100.00** | **100.00** |
| **Calculated analysis, %** | | | |
| Crude protein | 20.55 | 20.31 | 19.55 |
| Lysine | 1.53 | 1.37 | 1.27 |
| Methionine | 0.46 | 0.39 | 0.37 |
| Calcium | 0.88 | 0.83 | 0.74 |
| Phosphorous | 0.75 | 0.65 | 0.61 |

\* Zinc oxide or control diets were prepared by mixing zinc oxide (Maximo 720; Zinc Nacion, Monterrey, Nuevo León, Mexico) or ground corn, respectively, with basal diet consisting of the major portion of the ground corn and all other common ingredients. Control diets contained 14.2 ppm of copper, 113 ppm of iron, and 113 ppm of zinc.
† Archer Daniels Midland Co (Decatur, Illinois).
‡ ANS Swine Breeder Premix manufactured for Agri-Nutrition Services, Inc (Shakopee, Minnesota). Trace minerals in sulfate forms were in a polysaccharide complex.

each pen at weaning and at 7 and 49 days post-weaning. The same pig was used for each collection. On each occasion, barrows were placed supine on a v-board and approximately 7 mL of blood was collected via jugular venipuncture (20 gauge, 2.54 cm-long needle) into a Vacutainer tube (Becton, Dickinson and Company, Franklin Lakes, New Jersey) containing EDTA. Blood was used for complete blood counts conducted with a Coulter Multisizer 3 cell counter (Beckman Coulter, Inc, Brea, California) by Animal Laboratory Services of the Virginia-Maryland College of Veterinary Medicine (Blacksburg, Virginia). The following hematological determinations were made: number of red blood cells, reticulocytes, white blood cells, neutrophils, lymphocytes, monocytes,

eosinophils, basophils, and platelets, percentage of reticulocytes, hemoglobin concentration, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin concentration, red blood cell distribution width, and mean platelet volume.

## Statistical analysis

Data were subjected to ANOVA using the PROC MIXED procedure of SAS (SAS Institute Inc, Cary, North Carolina). Body weights, ADG, ADFI, and G:F were analyzed using a model that included pig size, number of iron doses, diet, and all two- and three-way interactions as possible sources of variation. Block was included as a random variable and pen served as the experimental unit. A repeated measures model was used

for analyzing hematological characteristics and included pig size, number of iron doses, diet, day, and all two-, three-, and four-way interactions as possible sources of variation. Block was included as a random variable and individual pig was the experimental unit. Individual means were compared using the LSMEANS option of PROC MIXED and were adjusted using the Tukey-Kramer procedure. Differences in means were considered statistically significant at $P < .05$ and tendencies declared at $P < .1$.

Additionally, the percentage of large and small pigs that were anemic at weaning (hemoglobin concentrations < 9.0 g/dL)[2] were compared using chi-square analysis. Hematological measures in anemic and non-anemic pigs at weaning were compared using ANOVA with a model that included anemic

**Table 2:** Least Squares Means (SE) of hematology characteristics in weaned pigs classified as anemic (n = 14) or not anemic (n = 33) based on circulating hemoglobin concentrations*

| Hematological parameter | Reference values[†] | Anemic | Not anemic | P[‡] |
|---|---|---|---|---|
| Hemoglobin, g/dL | 9 - 14 | 7.90 (0.26) | 10.35 (0.18) | .004 |
| Hematocrit, % | 26 - 41 | 27.21 (0.89) | 35.02 (0.64) | .004 |
| Red blood cells, × $10^6$ cells/μL | 5.3 - 8.0 | 5.31 (0.15) | 6.22 (0.10) | .01 |
| Mean corpuscular volume, fL | 42 - 62 | 51.55 (1.66) | 56.42 (0.39) | .04 |
| Mean corpuscular hemoglobin, g/dL | NR | 29.16 (0.25) | 29.54 (0.17) | .28 |
| Red blood cell distribution width, % | NR | 28.24 (0.74) | 20.19 (0.58) | .003 |
| Reticulocytes, % | NR | 4.22 (0.58) | 5.70 (0.41) | .11 |
| Reticulocytes, × $10^3$ cells/μL | NR | 228.33 (35.40) | 352.89 (24.22) | .06 |
| White blood cells, × $10^3$ cells/μL | 8.7 - 37.9 | 8.93 (0.81) | 9.02 (0.56) | .93 |
| Neutrophils, × $10^3$ cells/μL | 2.5 - 23 segmented 0.0 - 3.1 bands | 2.79 (0.58) | 3.71 (0.40) | .26 |
| Lymphocytes, × $10^3$ cells/μL | 2.2 - 16 | 5.06 (0.41) | 4.71 (0.36) | .39 |
| Monocytes, × $10^3$ cells/μL | 0.001 - 5 | 0.30 (0.04) | 0.27 (0.02) | .50 |
| Eosinophils, × $10^3$ cells/μL | 0 - 1.8 | 0.31 (0.07) | 0.25 (0.05) | .47 |
| Basophils, × $10^3$ cells/μL | 0 - 0.5 | 0.10 (0.02) | 0.07 (0.01) | .22 |
| Platelets, × $10^3$ cells/μL | NR | 617.47 (43.98) | 676.59 (33.15) | .30 |
| Mean platelet volume, fL | NR | 8.60 (0.64) | 8.86 (0.57) | .62 |

\*   Pigs with circulating hemoglobin < 9.0 g/dL were classified as anemic.[2] Blood was sampled from large or small (body weight [SE], 7.91 [0.13] and 5.36 [0.19] kg, respectively) barrows at weaning and the proportion of animals that were anemic tended to be greater (P = .07) for large (10 of 24; 41.7%) compared to small (4 of 23; 17.4%) pigs.

†   Reference values from Bhattarai et al.[2]

‡   Hematological measures were compared using ANOVA with a model that included anemic status (yes or no) as the main source of variation. Block and weaning weight were used as covariates.

NR = not reported.

status (yes or no) as the main source of variation. Block and weaning weight were used as covariates.

## Results

### Incidence of anemia in pigs at weaning

The blood sample from one small pig clotted before laboratory analyses were conducted, so data presented here represents a total of 23 small pigs and 24 large pigs. The proportion of animals that were anemic tended to be greater (P = .07) for large (10 of 24; 41.7%) compared to small (4 of 23; 17.4%) pigs. Hemoglobin concentrations (P = .004), hematocrit (P = .004), the number of red blood cells (P = .01), and mean corpuscular volume (P = .04) were less and the number of reticulocytes tended (P = .06) to be less in anemic pigs as compared to non-anemic pigs (Table 2). In contrast, red blood cell distribution width was greater (P = .003) in the anemic individuals.

### Hematology characteristics

Except for the interaction of pig size and day, there were no interactions of main effects on hematology characteristics. Hemoglobin concentrations (P = .01), hematocrit (P = .05), mean corpuscular volume (P < .001), and red blood cell distribution width (P = .004) (Figure 1) as well as the number of red blood cells (P = .06) and mean corpuscular hemoglobin (P = .009) (Figure 2) were affected or tended to be affected by the interaction of pig size and day. Hemoglobin concentration (P = .02) and hematocrit (P = .05) were less (P < .05) in large versus small pigs on day 0, but not on other days; mean corpuscular volume was less and red blood cell distribution width was greater in large pigs versus small pigs on days 0 (P < .001 and P < .001, respectively) and 7 (P = .008 and P = .002, respectively), but not on day 49 (Figure 1). For large pigs, the number of red blood cells tended to increase (P = .06) from day 0 to day 7 and then remained similar (P = .78) until day 49; mean corpuscular hemoglobin

concentration increased (P = .007) from day 0 to day 7 and further increased (P < .001) to day 49. For small pigs, the number of red blood cells tended to increase (P = .06) from day 0 to day 7 and from day 7 to day 49 (P = .06); mean corpuscular hemoglobin concentrations increased from day 0 to day 7 (P < .001) and tended to increase (P = .08) until day 49 (Figure 2).

Table 3 contains hematology characteristics in nursery pigs as affected by the main effects of pig size, number of iron doses, diet, and day (day 0, 7, or 49 post-weaning). Mean corpuscular volume was less (P < .001) and hemoglobin (P = .07) and mean corpuscular hemoglobin (P = .09) tended to be less in large compared to small pigs. In contrast, red blood cell distribution width was greater (P < .001) in the large versus small pigs. Size of pig did not affect other hematology characteristics. Except for a tendency (P = .09) for the number of white blood cells to be greater in pigs receiving a dose of

**Figure 1:** Hematology characteristics in blood collected from large and small pigs at weaning (day 0) and at days 7 and 49 post-weaning. Data were subjected to ANOVA for repeated measures. The model included size of pig, number of iron treatments, diet, day and all two-, three- and four-way interactions as possible sources of variation. Interaction of pig size and day for A, hemoglobin concentrations ($P = .01$); B, hematocrit ($P = .05$); C, mean corpuscular volume ($P < .001$); and D, red blood cell distribution width ($P = .004$). For each characteristic, days on which values differed ($P < .05$) for large and small pigs are indicated by an *.
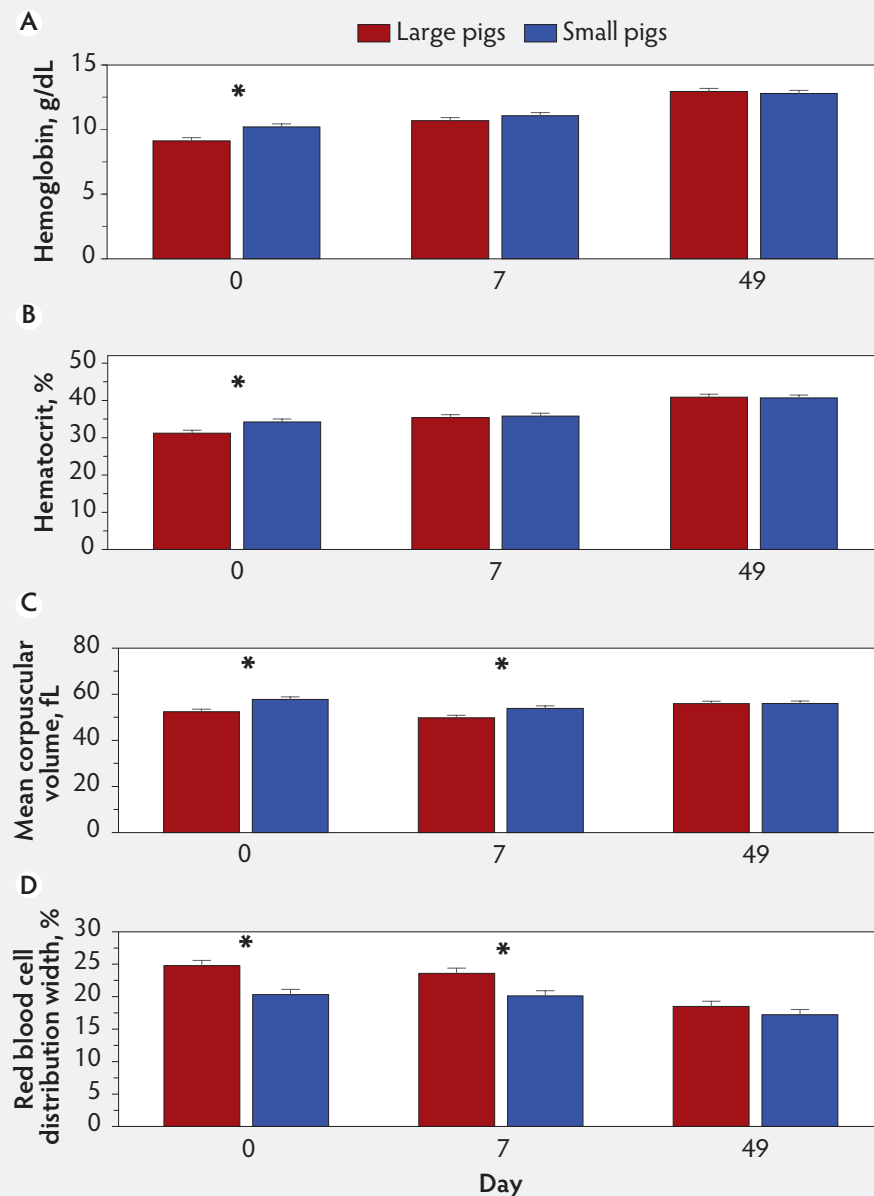
iron only at birth compared to at birth and at weaning, hematology characteristics were not affected by the number of iron doses. Mean corpuscular hemoglobin tended to be greater ($P = .06$) in zinc-supplemented pigs compared to controls, but diet did not affect other hematology characteristics.

Other than the number of eosinophils ($P = .31$) and mean platelet volume ($P = .45$),

all hematology measures were affected by day. Red blood cell number, hemoglobin concentration, hematocrit, mean corpuscular hemoglobin concentration, and the number of monocytes increased ($P < .001$) from day 0 to day 7 and further increased ($P < .001$) from day 7 to day 49. The number of white blood cells ($P < .001$), neutrophils ($P < .001$), lymphocytes ($P = .009$),

and basophils ($P = .01$) increased from day 0 to day 7, and then remained similar until day 49. The number of platelets decreased ($P < .001$) from day 0 to day 7 and further decreased ($P < .001$) from day 7 to day 49. Red blood cell distribution width was similar ($P = .28$) on days 0 and 7 and then decreased ($P < .001$) from day 7 to day 49. Reticulocyte numbers decreased ($P < .001$) from day 0 to day 7 and then tended to increase ($P = .09$) from day 7 to 49, however, numbers on day 49 were less ($P < .001$) than numbers on day 0. Mean corpuscular volume decreased ($P < .001$) from day 0 to day 7 but increased ($P < .001$) to levels on day 49 that were not different ($P = .29$) from those on day 0. Reticulocyte percentage decreased ($P < .001$) from day 0 to 7 and tended to increase ($P = .09$) to day 49, however levels at day 49 were less ($P < .001$) than levels at day 0.

## Growth performance

There were a few two-way interactions of main effects on various growth measures, however, there were no three-way interactions among pig size, number of iron doses, and diet. Between day 22 and 49 post-weaning, ADFI ($P = .06$), but not ADG ($P = .25$) or G:F ($P = .61$), tended to be affected by an interaction between pig size and diet (Figure 3). In large ($P = .06$) but not small ($P = .91$) pigs, ADFI was greater when the diet was supplemented with 2000 ppm of zinc. For the period between day 22 and 49, G:F ($P = .05$), but not ADG ($P = .29$) or ADFI ($P = .80$), was affected by an interaction of the number of iron doses and diet (Figure 4). Dietary supplementation with 2000 ppm of zinc decreased ($P = .05$) G:F only in pigs receiving the extra dose of iron at weaning. For the entire experiment (day 0 to 49), the interaction between pig size and diet tended to affect ($P = .09$) ADFI but not ADG ($P = .30$) or G:F ($P = .71$) (Figure 5). The zinc diet tended to increase ADFI in large ($P = .09$) but not small ($P = .46$) pigs.

Table 4 summarizes weekly body weights and growth performance in nursery pigs as affected by the main effects of pig size, number of iron doses, and diet. Large pigs weighed more than small pigs on each week of the experiment. From day 0 to 7, pig size did not affect ADG ($P = .15$) or ADFI ($P = .12$), but G:F was greater ($P = .01$) in the small individuals. For days 8 to 21 and 22 to 49, ADG and ADFI were greater ($P < .001$) in the large versus small pigs. For days 8 to 21, G:F was similar ($P = .35$)

between pig size groups, but from day 22 to 49, G:F was greater ($P$ = .006) in the small individuals. For the overall trial (day 0 to 49 post-weaning), ADG and ADFI were greater ($P$ < .001) in large pigs, and G:F was greater ($P$ = .002) in small animals.

With the exception of a tendency for greater G:F from day 22 to 49 ($P$ = .09) in animals receiving only one dose of iron, there were no effects ($P$ > .13) of number of iron doses on body weights or growth performance measures.

Compared to controls, zinc-supplemented pigs had greater body weights on days 7 ($P$ = .004), 14 ($P$ < .001), 21 ($P$ = .05), and 28 ($P$ = .02), and a tendency ($P$ = .08) for greater body weights on day 35. Body weights at days 42 ($P$ = .12) and 49 ($P$ = .26) were not affected by experimental diet. From day 0 to 7, zinc-fed pigs had greater ($P$ = .002) ADG and G:F, but similar ($P$ = .14) ADFI compared to controls. For the period between days 8 and 21, ADG ($P$ = .02) and ADFI ($P$ < .001) were greater in pigs fed the zinc diet, but G:F tended to be greater ($P$ = .09) for pigs fed control diets. The ADG was similar ($P$ = .86), ADFI was greater ($P$ = .007), and G:F was less ($P$ = .005) for zinc-supplemented pigs compared with controls for day 22 to 49. Over the course of the trial, pigs fed diets supplemented with zinc had greater ADFI ($P$ < .001) but similar ADG ($P$ = .18) and a lower G:F ($P$ = .009) compared with controls.

## Discussion

### Incidence of anemia in pigs at weaning

Iron is a requisite component of hemoglobin, a protein molecule in red blood cells that carries oxygen from the lungs to bodily tissues and returns carbon dioxide from tissues back to the lungs. If iron levels in the body are inadequate to maintain a normal concentration of hemoglobin in the blood, iron deficiency anemia occurs. In the neonatal pig, iron deficiency anemia can be prevented by parenteral administration of iron,[13] and on modern swine farms, an IM injection of 100 to 200 mg iron dextran given within a few days after birth is common.[1]

The timing, dosage, and number of injections of iron dextran, however, varies widely among commercial operations.[1] Moreover, it is evident that despite treatment with iron early in life, a significant number of pigs, particularly the fastest growing animals within a litter, are iron deficient or anemic at weaning.[2,3]

For the current investigation, pigs with hemoglobin concentrations < 9.0 g/dL were classified as anemic.[2] Based on that criterion, a greater proportion of large pigs (41.7%) was classified as anemic at weaning compared with small pigs (17.4%). These results are consistent with previous studies[2,3] that also demonstrated an increased risk of anemia at weaning in larger, faster-growing pigs. The overall percentage of pigs in the current study that were classified anemic (29.8%) was greater than the proportion so classified (6%) in a previous study,[3] although the criterion used to identify the anemic condition was similar. Perhaps this difference reflects the greater dose of iron dextran (200 mg) administered at birth on the commercial farms in the previous study[3] compared to the dose (100 mg) used in the current experiment. However, the proportion of pigs classified as anemic in the current study (29.8%) was similar to the proportion of pigs (35%) categorized as either anemic (hemoglobin concentrations ≤ 9.0 g/dL) or iron deficient (hemoglobin concentrations > 9.0 and ≤ 11.0 g/dL) in a previous report.[3]

Red blood cell numbers, hematocrit, mean corpuscular volume, and the number of reticulocytes were less for anemic pigs compared with non-anemic counterparts, although mean values in both groups of animals were within reference ranges and considered normal.[14] Red blood cell distribution width, a measure of variability in the size of cells, was greater in anemic individuals, which is consistent with iron deficiency anemia.[2]

### Hematology characteristics

Hemoglobin concentrations and hematocrit were less in large pigs than in small pigs at weaning. In addition, mean corpuscular volume was less and red blood cell distribution width was greater at both weaning and 7 days post-weaning in large versus small pigs. These results support previous reports[2,3] in which larger and faster-growing pigs are at a greater risk of developing anemia compared with small pigs. Additionally, number of red blood cells increased in large

**Figure 2:** Red blood cell and mean corpuscular hemoglobin concentrations in large and small pigs at weaning (day 0) and days 7 and 49 post-weaning. Data were subjected to ANOVA for repeated measures. The model included size of pig, number of iron treatments, diet, day, and all two-, three-, and four-way interactions as possible sources of variation. Interaction of pig size and day for A, red blood cell concentration ($P$ = .06) and B, mean corpuscular hemoglobin concentration ($P$ = .009). Within pig size for each hematology characteristic, bars with different superscripts differ (Figure A: $P$ = .06 and Figure B: $P$ < .05).
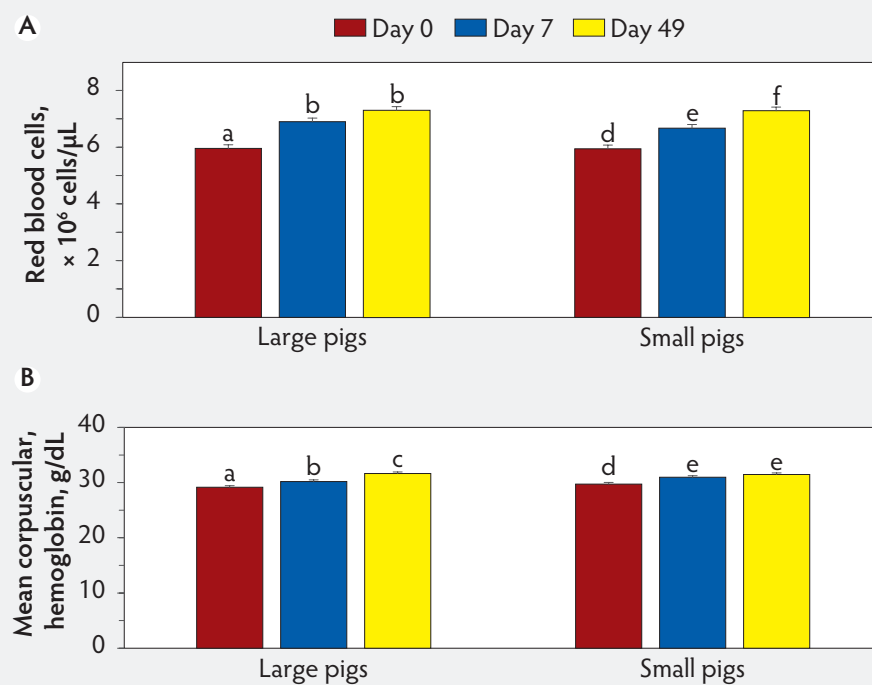
**Table 3:** Hematology characteristics of large and small nursery pigs treated intramuscularly with 100 mg iron dextran at birth or at birth and at weaning and fed control or zinc supplemented (2000 ppm) diets for 49 days

| Hematological parameter | Size of pig | | | | Iron treatments | | | | Diet | | | | Day† | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Large (n = 24) | Small (n = 23) | SE | P‡ | Birth (n = 24) | Birth + weaning (n = 23) | SE | P‡ | Control (n = 24) | Zinc (n = 23) | SE | P‡ | 0 (n = 47) | 7 (n = 47) | 49 (n = 47) | SE | P‡ |
| Red blood cells, × 10^6 cells/µL* | 6.80 | 6.63 | 0.14 | .23 | 6.72 | 6.71 | 0.14 | .93 | 6.72 | 6.71 | 0.14 | .98 | 5.95$^a$ | 6.90$^b$ | 7.30$^c$ | 0.10 | < .001 |
| Hemoglobin, g/dL* | 10.92 | 11.35 | 0.24 | .07 | 11.22 | 11.05 | 0.24 | .46 | 11.03 | 11.24 | 0.24 | .36 | 9.66$^a$ | 10.88$^b$ | 12.87$^c$ | 0.20 | < .001 |
| Hematocrit, %* | 35.85 | 36.90 | 0.70 | .14 | 36.64 | 36.11 | 0.70 | .45 | 36.27 | 36.48 | 0.70 | .77 | 32.74$^a$ | 35.60$^b$ | 40.78$^c$ | 0.70 | < .001 |
| Mean corpuscular volume, fL* | 52.72 | 55.89 | 0.86 | < .001 | 54.70 | 53.90 | 0.86 | .35 | 54.18 | 54.43 | 0.86 | .77 | 55.12$^a$ | 51.85$^b$ | 55.94$^a$ | 0.54 | < .001 |
| Mean corpuscular hemoglobin, g/dL* | 30.33 | 30.72 | 0.23 | .09 | 30.54 | 30.50 | 0.23 | .86 | 30.30 | 30.74 | 0.23 | .06 | 29.44$^a$ | 30.58$^b$ | 31.55$^c$ | 0.16 | < .001 |
| Red blood cell distribution width, %* | 22.29 | 19.21 | 0.84 | < .001 | 20.89 | 20.61 | 0.84 | .74 | 21.27 | 20.23 | 0.84 | .22 | 22.55$^a$ | 21.85$^a$ | 17.85$^b$ | 0.48 | < .001 |
| Reticulocytes, % | 3.75 | 3.93 | 0.30 | .56 | 3.97 | 3.71 | 0.30 | .40 | 4.01 | 3.67 | 0.30 | .27 | 5.36$^a$ | 2.74$^b$ | 3.43$^a$ | 0.33 | < .001 |
| Reticulocytes, × 10^3 cells/µL | 249.9 | 255.9 | 19.8 | .76 | 261.9 | 243.9 | 19.8 | .36 | 261.9 | 243.9 | 19.8 | .37 | 318.4$^a$ | 190.3$^b$ | 249.9$^c$ | 21.6 | < .001 |
| White blood cells, × 10^3 cells/µL | 13.27 | 12.61 | 0.59 | .26 | 13.45 | 12.43 | 0.59 | .09 | 13.14 | 12.73 | 0.59 | .49 | 8.97$^a$ | 14.35$^b$ | 15.50$^b$ | 0.64 | < .001 |
| Neutrophils, × 10^3 cells/µL | 4.73 | 4.78 | 0.37 | .89 | 4.96 | 4.55 | 0.37 | .27 | 4.91 | 4.60 | 0.37 | .40 | 3.46$^a$ | 5.86$^b$ | 4.94$^b$ | 0.51 | < .001 |
| Lymphocytes, × 10^3 cells/µL | 8.36 | 6.69 | 1.02 | .10 | 8.27 | 6.79 | 1.02 | .15 | 7.04 | 8.01 | 0.92 | .34 | 4.82$^a$ | 8.59$^b$ | 9.18$^b$ | 1.28 | .001 |
| Monocytes, × 10^3 cells/µL | 0.60 | 0.66 | 0.06 | .24 | 0.65 | 0.61 | 0.06 | .52 | 0.65 | 0.61 | 0.06 | .54 | 0.27$^a$ | 0.73$^b$ | 0.89$^c$ | 0.05 | < .001 |
| Eosinophils, × 10^3 cells/µL | 0.28 | 0.27 | 0.04 | .70 | 0.29 | 0.26 | 0.04 | .40 | 0.29 | 0.26 | 0.04 | .40 | 0.26 | 0.31 | 0.24 | 0.05 | .31 |
| Basophils, × 10^3 cells/µL | 0.11 | 0.13 | 0.02 | .29 | 0.13 | 0.11 | 0.02 | .17 | 0.12 | 0.12 | 0.02 | .92 | 0.08$^a$ | 0.12$^b$ | 0.15$^b$ | 0.01 | < .001 |
| Platelets, × 10^3 cells/µL | 501.6 | 509.4 | 33.9 | .82 | 513.0 | 498.0 | 33.9 | .66 | 506.3 | 504.7 | 33.9 | .96 | 664.6$^a$ | 515.3$^b$ | 336.6$^c$ | 30.1 | < .001 |
| Mean platelet volume, fL | 8.59 | 8.71 | 0.27 | .65 | 8.66 | 8.64 | 0.27 | .93 | 8.73 | 8.58 | 0.27 | .59 | 8.75 | 8.45 | 8.76 | 0.28 | .45 |

\* Affected (P < .05) or tended to be affected (P = .06) by interaction of pig size and day.
† For the main effect of day, values with different superscripts (a,b,c) differ (P < .05).
‡ Data were subjected to ANOVA for repeated measures. The model included size of pig, number of iron treatments, diet, day, and all two-, three-, and four-way interactions as possible sources of variation.

pigs from weaning to day 7 post-weaning and then remained constant through the end of the current trial. In contrast, mean corpuscular hemoglobin concentrations in large pigs increased throughout. The situation was different in small pigs in that number of red blood cells increased from weaning to day 49 post-weaning, but mean corpuscular hemoglobin concentrations increased from day 0 to day 7 and then remained constant. In general, values for other hematological characteristics reported here were affected by day post-weaning with absolute values and trends over time consistent with previous reports.[15-17] With the exception of a tendency for mean corpuscular hemoglobin concentrations to be greater in zinc-fed pigs than controls, diet did not affect hematology characteristics. That hemoglobin concentrations and hematocrit were similar between groups suggests that the zinc-supplemented diets did not have an overt effect on iron absorption and utilization. Our results are in general agreement with a previous study[18] in which, except for an increased percentage of lymphocytes, hematology profiles of weaned pigs fed pharmacological levels of dietary zinc were similar to control-fed animals.

In the current experiment, pigs treated at both birth and at weaning with 100 mg iron dextran tended to have fewer white blood cells than pigs that received a dose of iron at birth only. The biological significance of this finding is not readily apparent because excess iron in the blood stream of neonatal pigs can cause polyarthritis, septicemia, and colibacillosis, which one would expect to increase the number of white blood cells.[19] Also, leukopenia has actually been associated with low hemoglobin concentrations in humans suffering from severe iron deficiency anemia.[20]

Hemoglobin concentrations were not affected by the additional iron injection at weaning in the experiment reported here. A second injection of 200 mg iron dextran administered 1 or 7 days before weaning at 21 or 28 days of age also failed to consistently increase hemoglobin concentrations in a case study conducted on 5 commercial pig farms.[1] In pigs that received 200 mg of iron dextran within 24 hours after birth, hemoglobin concentrations and hematocrit increased only slightly after an additional treatment with iron at weaning (17 days of age), and by 21 days post-weaning, values were actually less compared with pigs that received iron only at birth.[21] A second injection of 200 mg iron dextran at 21 days of age increased hemoglobin concentration but not hematocrit in pigs

at weaning (28 days of age), but at 21 days post-weaning, neither hematology characteristics were affected by the second treatment.[22] For pigs weaned and blood sampled at 34 days of age, a second injection of 200 mg iron dextran administered at 20 days of age also increased hemoglobin concentrations.[23] Thus it appears that efficacy of a second iron dose at weaning to increase hemoglobin is impacted by the timing of administration relative to weaning and is probably more effective in pigs weaned at older ages. Moreover, differences in iron statuses between iron-injected and control animals could be obscured by dietary consumption of iron.

## Growth performance

In the current study, pigs classified as large at weaning (approximately 7.9 kg) weighed approximately 2.5 kg more than pigs classified as small (approximately 5.4 kg). That large pigs consumed more feed and grew faster during the nursery phase of production is consistent with previous reports.[16,24-27] Feed conversion efficiency is a function of body weight, and as a pig grows, it becomes less efficient at converting feed into body weight gain.[28] Accordingly, in the current study, small pigs at weaning displayed greater G:F during the nursery phase of production compared to large pigs at weaning.

**Figure 3:** Growth performance between 22 and 49 days post-weaning in pigs classified as large or small at weaning (21 days of age) and that were fed control diets or diets supplemented with 2000 ppm of zinc. Data were subjected to ANOVA using a model that included pig size, number of iron doses, diet, and all two- and three-way interactions as possible sources of variation. Interaction between pig size at weaning and diet for A, ADG ($P$ = .25), B, ADFI ($P$ = .06), and C, G:F ($P$ = 0.61). An * indicates differences between diets within size of pig ($P$ = .06). ADG = Average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio.
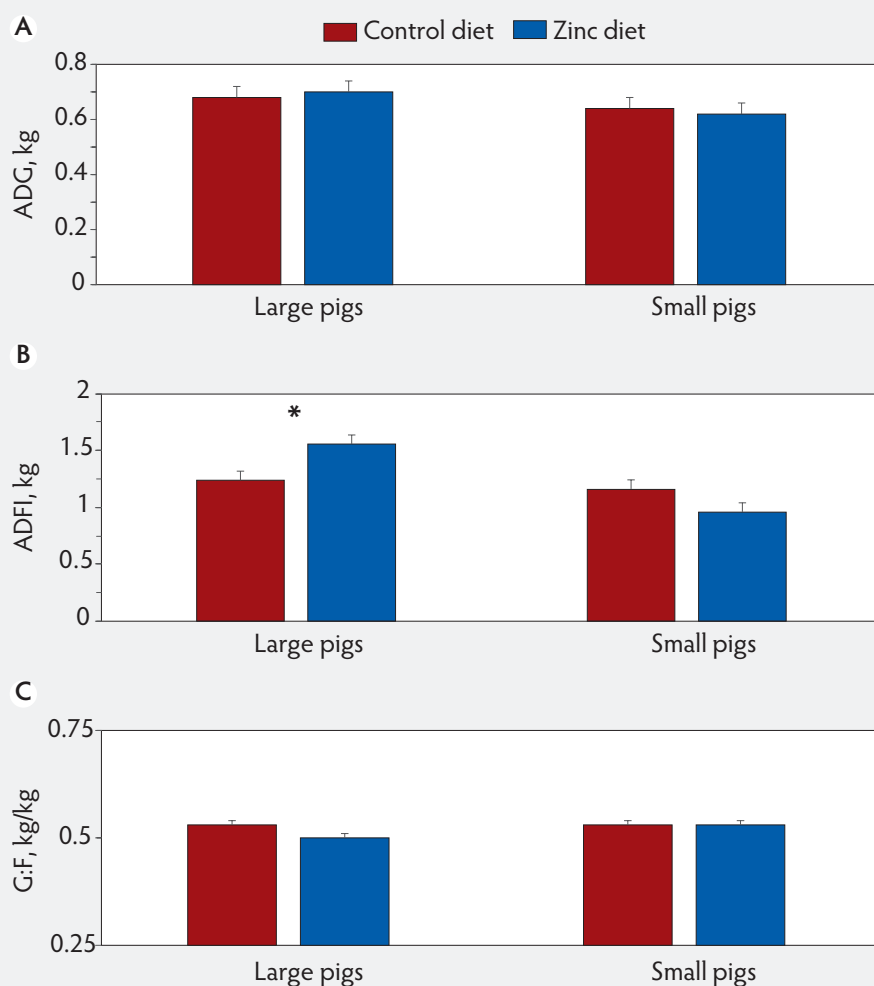
In general, a second injection of iron dextran did not affect the various growth performance measures. However, between days 22 and 49 post-weaning, a second treatment with iron at weaning tended to decrease G:F in zinc-fed, but not control pigs. A biological explanation for this finding is not readily apparent, but plasma zinc concentrations were increased by increasing dietary concentrations of iron.[29] Perhaps by the end of the current 49-day study, blood zinc concentrations in zinc-fed pigs that also received a dose of iron at weaning were reaching a level that was detrimental to feed conversion efficiency.

Studies designed to determine the effects of additional iron administered by either increasing the dosage given at birth or by an additional treatment during the suckling period or at weaning on post-weaning growth have yielded equivocal results. Increased post-weaning ADG in pigs receiving injections of 200 mg iron at birth and 200 mg at 7 to 14 days prior to weaning compared to pigs receiving 200 mg iron only at birth were reported.[22,23] In contrast, nursery growth performance was not influenced or was only slightly modified by increasing the dosage of iron given at birth from 200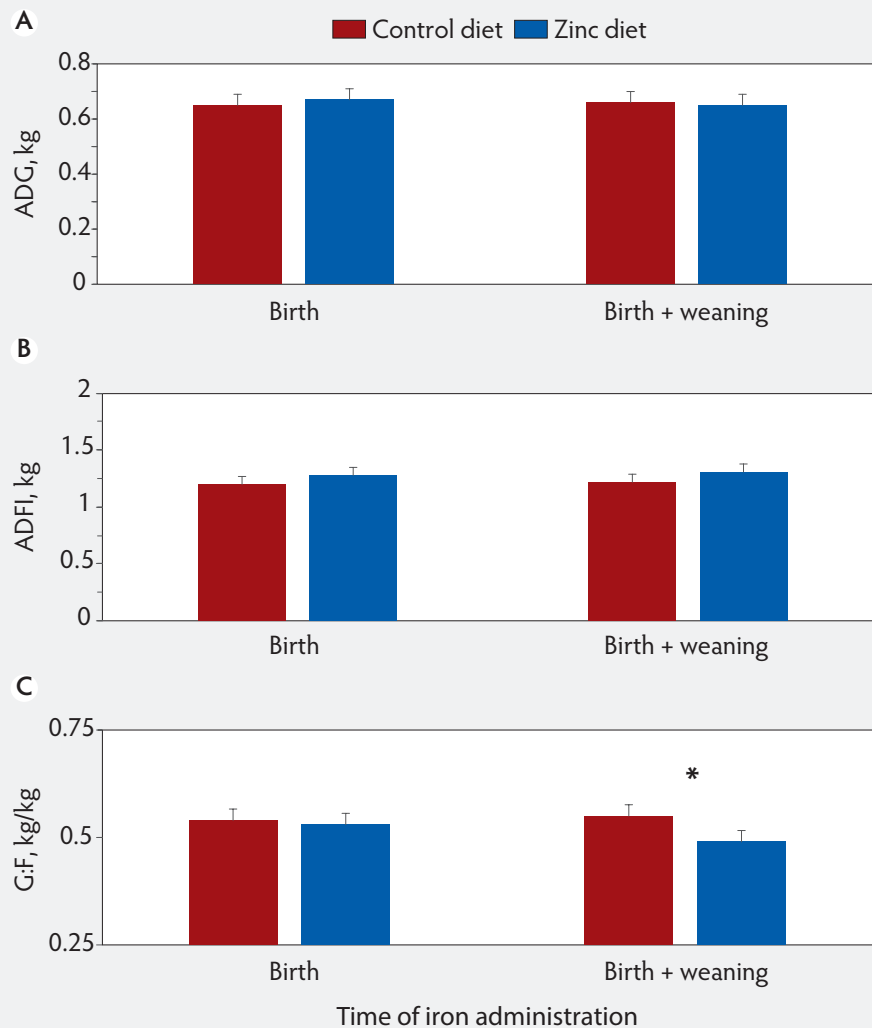 to 300 mg[19,29] or by injecting 200 mg at birth and 100 to 200 mg at day 17 of age or at weaning.[21,29] Finally, in the current study, ADFI was increased by dietary zinc and this increase tended to be most pronounced in large size pigs. Increased ADFI in zinc-fed pigs was first detected between day 8 and 21 of the experiment and was subsequently demonstrated for the period from day 22 to 49 and the overall trial. The stimulatory effect of pharmacological concentrations of dietary zinc on feed consumption has been previously reported.[7]

Increased growth responses in nursery pigs provided pharmacological concentrations of dietary zinc oxide have been well-documented, where experimental diets in most studies had been fed for 28 days.[5-8] For example, in a previous study,[7] weaned pigs were fed diets containing zinc oxide at levels of 0, 500, 1000, 2000, or 3000 ppm for 28 days. As dietary zinc oxide increased, both early weaned pigs (< 15 days of age) and pigs weaned after 20 days of age had greater ADG and ADFI. Nonetheless, early weaned pigs also displayed greater G:F, which was not observed in the pigs weaned at 20 days of age. Responses for both pig groups plateaued at 2000 ppm.[7] For pigs weaned at 21 days of age in the current experiment, enhanced ADG and G:F in response to 2000 ppm zinc was limited to the first 21 days of the experiment. Moreover, feed conversion efficiency was poorer in zinc-fed pigs compared to controls for the period from day 22 to 49. It has been suggested that if pharmacological doses of zinc are fed for too long (> 5 weeks) symptoms of toxicity and deficiencies of other trace minerals can result.[12] A perturbed trace mineral balance could explain our finding that supplemental zinc decreased feed conversion efficiency from day 22 to 49 of feeding in pigs receiving a second 100 mg dose of iron at weaning.

**Figure 4:** Growth performance between days 22 and 49 post-weaning in pigs that received 100 mg iron dextran at birth or 100 mg iron at birth and at weaning and were fed control diets or diets supplemented with 2000 ppm of zinc. Data were subjected to ANOVA using a model that included pig size, number of iron doses, diet, and all two- and three-way interactions as possible sources of variation. Interaction between the number of iron treatments and diet for A, ADG ($P$ = .29), B, ADFI ($P$ = .80), and C, G:F ($P$ = .05). An * indicates differences between diets within number of iron doses ($P$ = .05). ADG = Average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio.



## Implications

- The incidence of anemia at weaning was significant, especially for the largest individuals, but was not exacerbated by dietary zinc supplementation.
- A second dose of iron dextran administered at weaning had minimal effects on nursery growth performance.
- Pharmacological levels of dietary zinc enhanced nursery growth performance during the early post-weaning period but waned as the pigs aged.
- Supplemental zinc decreased G:F from day 22 to 49 in pigs that received a second dose of iron at weaning, perhaps due to trace mineral imbalances occasioned by the prolonged feeding of zinc.

- Zinc supplementation resulted in increased feed consumption by larger, faster-growing pigs.

## Acknowledgement

## Conflict of interest

None reported.

## Disclaimer

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**Figure 5:** Growth performance between days 0 and 49 post-weaning in pigs classified as large or small at weaning (21 days of age) and that were fed control diets or diets supplemented with 2000 ppm of zinc. Data were subjected to ANOVA using a model that included pig size, number of iron doses, diet, and all two- and three-way interactions as possible sources of variation. Interaction between size of pig and diet for A, ADG ($P$ = .30), B, ADFI ($P$ = .09), and C, G:F ($P$ = .72). An * indicates differences between diets within size of pig ($P$ = .09). ADG = Average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio.
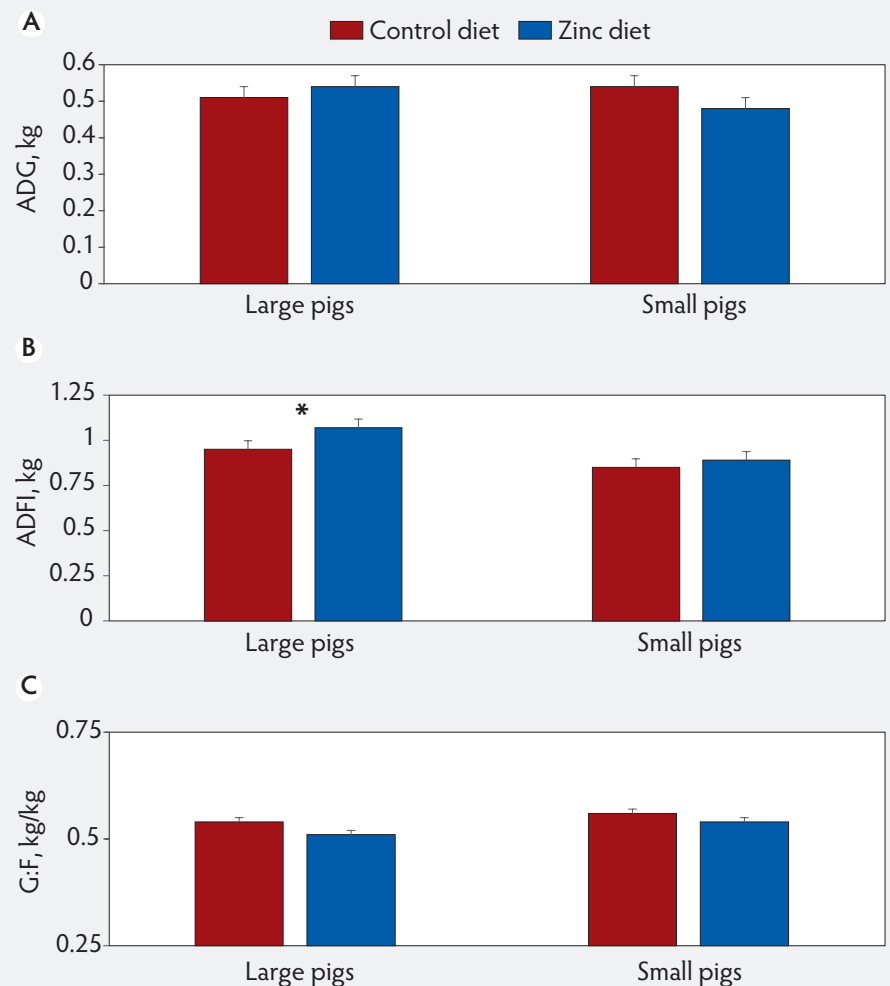
**Table 4:** Body weight and growth performance of large and small nursery pigs injected once or twice with iron dextran (100 mg) and fed control or zinc supplemented (2000 ppm) diets for 49 days

| | Size of pig | | | | Number of iron injections | | | | Diet | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Large | Small | SE | P* | One | Two | SE | P* | Control | Zinc | SE | P* |
| Number of pens | 24 | 24 | | | 24 | 24 | | | 24 | 24 | | |
| **Body weights, kg** | | | | | | | | | | | | |
| Weaning, Day 0 | 7.91 | 5.38 | 0.06 | < .001 | 6.63 | 6.65 | 0.06 | .73 | 6.64 | 6.64 | 0.06 | .99 |
| Day 7 | 8.54 | 6.14 | 0.10 | < .001 | 7.31 | 7.37 | 0.10 | .57 | 7.19 | 7.49 | 0.10 | .004 |
| Day 14 | 10.67 | 8.03 | 0.14 | < .001 | 9.28 | 9.41 | 0.14 | .37 | 9.08 | 9.62 | 0.14 | < .001 |
| Day 21 | 14.31 | 11.10 | 0.24 | < .001 | 12.55 | 12.85 | 0.24 | .23 | 12.34 | 13.07 | 0.24 | .005 |
| Day 28 | 18.89 | 14.80 | 0.31 | < .001 | 16.67 | 17.01 | 0.31 | .28 | 16.45 | 17.23 | 0.38 | .02 |
| Day 35 | 24.07 | 19.52 | 0.43 | < .001 | 21.70 | 21.89 | 0.43 | .68 | 21.41 | 22.18 | 0.43 | .08 |
| Day 42 | 29.75 | 24.50 | 0.92 | < .001 | 27.06 | 27.19 | 0.92 | .80 | 26.72 | 27.53 | 0.92 | .12 |
| Day 49 | 33.90 | 28.66 | 0.54 | < .001 | 31.36 | 31.20 | 0.54 | .76 | 30.97 | 31.59 | 0.54 | .26 |
| **Day 0 to 7** | | | | | | | | | | | | |
| ADG, kg/day | 0.09 | 0.11 | 0.01 | .15 | 0.10 | 0.10 | 0.01 | .74 | 0.08 | 0.12 | 0.01 | .002 |
| ADFI, kg/day | 0.28 | 0.25 | 0.02 | .12 | 0.27 | 0.26 | 0.02 | .66 | 0.25 | 0.28 | 0.02 | .14 |
| G:F, kg/kg | 0.32 | 0.44 | 0.04 | .01 | 0.36 | 0.40 | 0.04 | .37 | 0.31 | 0.45 | 0.04 | .002 |
| **Day 8 to 21** | | | | | | | | | | | | |
| ADG, kg/day | 0.41 | 0.35 | 0.02 | < .001 | 0.37 | 0.39 | 0.02 | .15 | 0.37 | 0.40 | 0.02 | .02 |
| ADFI, kg/day | 0.70 | 0.59 | 0.03 | < .001 | 0.64 | 0.66 | 0.03 | .29 | 0.60 | 0.70 | 0.03 | < .001 |
| G:F, kg/kg | 0.59 | 0.61 | 0.01 | .35 | 0.59 | 0.60 | 0.01 | .64 | 0.61 | 0.58 | 0.01 | .09 |
| **Day 22 to 49** | | | | | | | | | | | | |
| ADG, kg/day | 0.69 | 0.63 | 0.04 | < .001 | 0.66 | 0.65 | 0.04 | .56 | 0.65 | 0.66 | 0.04 | .86 |
| ADFI, kg/day† | 1.34 | 1.15 | 0.07 | < .001 | 1.24 | 1.26 | 0.07 | .36 | 1.21 | 1.29 | 0.07 | .006 |
| G:F, kg/kg‡ | 0.51 | 0.55 | 0.01 | .006 | 0.54 | 0.52 | 0.01 | .09 | 0.54 | 0.51 | 0.01 | .005 |
| **Overall, Day 0 to 49** | | | | | | | | | | | | |
| ADG, kg/day§ | 0.52 | 0.47 | 0.02 | < .001 | 0.50 | 0.50 | 0.02 | .96 | 0.49 | 0.51 | 0.02 | .18 |
| ADFI, kg/day¶ | 1.01 | 0.86 | 0.04 | < .001 | 0.93 | 0.95 | 0.04 | .31 | 0.90 | 0.97 | 0.04 | < .001 |
| G:F, kg/kg | 0.52 | 0.55 | 0.01 | .002 | 0.54 | 0.53 | 0.01 | .13 | 0.55 | 0.52 | 0.01 | .01 |

\* Data were subjected to ANOVA using a model that included pig size, number of iron doses, diet, and all two- and three-way interactions as possible sources of variation.

† Tendency for effect (P = .06) of interaction between size of pig and diet.

‡ Affected (P = .05) by interaction of number of iron treatments and diet.

§ Tendency for effect (P = .10) of interaction between size of pig and number of iron treatments.

¶ Tendency for effect (P = .09) of interaction of size of pig and diet.

ADG = average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio.

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

### Temperature equivalents (approx)

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

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

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

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

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

# Sow behavior and productivity in a small stable group-housing system

Magnus Campler, PhD; Monique Pairis-Garcia, DVM, PhD; Justin Kieffer, DVM; Steven Moeller, PhD

## Summary

**Objectives:** To quantify behavior and productivity of females grouped in small static groups when fed using a single-entry/exit electronic sow feeder (ESF) over two consecutive gestation periods.

**Materials and methods:** Fifty-eight gilts with no previous experience in group gestation housing were enrolled into 3, static, successive cohorts (Cohort 1, n = 20; Cohort 2, n = 18; and Cohort 3, n = 20) at day 35 of gestation. Pigs were housed individually throughout the farrowing period, and pigs that were healthy were moved back into their respective groups for their second gestation (Cohort 1, n = 19; Cohort 2, n = 13; Cohort 3, n = 17). Pig behavior, social rank, and post-gestation productivity was quantified for each gestation period.

**Results:** Agonistic behaviors decreased between the first and second gestation ($P < .001$). High-ranked sows initiated more agonistic bouts around the ESF when compared to intermediate- and low-ranked sows ($P < .001$). Duration of active ($P = .78$) and inactive ($P = .76$) behaviors did not differ between gestation periods, but more active behaviors were observed near the ESF when compared to other areas of the pen ($P < .001$). High-ranked sows visited the feeder more frequently when compared to intermediate- and low-ranked sows ($P < .001$). No differences in subsequent litter or female productivity measures were found based on sow ranking.

**Implications:** Housing gestating females in small static groups with an ESF decreased aggression between the first and second parity without detrimentally affecting general pig behavior or productivity.

**Keywords:** swine, aggression, gestation, group housing, electronic sow feeder

### Resumen – Conducta y productividad de la hembra en un sistema de alojamiento de grupo pequeño estable

**Objetivos:** Valorar la conducta y productividad de las hembras agrupadas en grupos estáticos pequeños cuando se alimentaron utilizando un comedero electrónico para hembras (ESF por sus siglas en inglés) con entrada/salida única durante dos periodos consecutivos de gestación.

**Materiales y métodos:** En el día 35 de gestación, se agruparon cincuenta y ocho hembras primerizas, sin experiencia previa en alojamiento en grupo durante la gestación en 3 cohortes estáticos, sucesivos, (Cohorte 1, n = 20; Cohorte 2, n = 18; y Cohorte 3, n = 20). Las cerdas fueron alojadas individualmente durante el periodo de parto, las cerdas saludables fueron regresadas a sus grupos respectivos durante la segunda gestación (Cohorte 1, n = 19; Cohorte 2, n = 13; Cohorte 3, n = 17). Para cada periodo de gestación, se cuantificó la conducta de la cerda, la clasificación social, y la productividad post gestación.

**Resultados:** Las conductas agresivas disminuyeron entre la primera y la segunda gestación ($P < .001$). Las hembras de clasificación alta iniciaron más episodios combativos alrededor del ESF en comparación con las hembras de clasificación intermedia y baja ($P < .001$). La duración de las conductas activas ($P = .78$) e inactivas ($P = .76$) no difirieron entre los periodos de gestación, pero se observaron más conductas activas cerca del ESF al compararse con otras áreas del corral ($P < .001$). Las hembras de clasificación alta visitaron el alimentador más frecuentemente en comparación con las hembras de clasificación intermedia y baja ($P < .001$). En base a la clasificación de la hembra, no se encontraron diferencias en las medidas de la camada subsecuentes o productividad de las hembras.

**Implicaciones:** Alojar hembras gestantes en pequeños grupos estáticos con un ESF disminuyó la agresión entre la primera y segunda paridad sin afectar negativamente la productividad o la conducta general de las cerdas.

### Résumé – Comportement et productivité des truies dans un système d'hébergement en petit groupe stable

**Objectifs:** Quantifier le comportement et la productivité de femelles regroupées en petits groupes statiques lorsque nourries en utilisant un système électronique d'alimentation à entrée/sortie unique (ESF) au cours de deux périodes consécutives de gestation.

**Matériels et méthodes:** Cinquante-huit cochettes sans expérience préalable d'hébergement en groupe de gestation furent recrutées dans trois cohortes statiques successives (Cohorte 1, n = 20; Cohorte 2, n = 18; et Cohorte 3, n = 20) au 35e jours de gestation. Les porcs étaient logés individuellement durant la période de mise-bas, et les porcs qui étaient en santé ont été retournés dans leurs groupes respectifs pour la seconde gestation (Cohorte 1, n = 19; Cohorte 2, n = 13; Cohorte 3, n = 17). Le comportement des porcs, leur rang social, et

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la productivité post-gestation ont été quantifiés pour chaque période de gestation.

**Résultats:** Les comportements agonistiques diminuèrent entre la première et la seconde gestation ($P < .001$). Les truies de rang social élevé initièrent plus d'attaques agonistiques autour de l'ESF comparativement aux truies de rangs intermédiaires et faible ($P < .001$). La durée des comportements actifs ($P = .78$) et inactifs ($P = .76$) ne différaient pas entre les périodes de gestation, mais des comportements plus actifs étaient observés à proximité des ESF lorsque comparé aux autres endroits dans l'enclos ($P < .001$). Les truies de rang élevé visitèrent la mangeoire plus fréquemment comparativement aux truies de rangs intermédiaire et faible ($P < .001$). Aucune différence dans les portées subséquentes ou les mesures de productivité des femelles ne fut trouvée en fonction du rang social des truies.

**Implications:** L'hébergement de femelles gestantes en petits groupes statiques avec un ESF diminua l'agressivité entre la première et la deuxième parité sans affecter négativement le comportement général des porcs ou la productivité.

In the United States, legislation in 10 states currently mandates the use of group-housing systems to house pregnant sows during gestation, with Michigan and Ohio being the most recent states to pass legislation that will be implemented by 2019 and 2026 respectively.[1,2] Meeting the group housing mandate will require producers to either convert existing facilities or to build new. Regardless of approach, sow gestation housing must be constructed in a way that minimizes pig aggression while assuring optimal welfare, nutritional support, and productivity. Previous research has shown the transition from gestation stalls to group housing can improve breeding female welfare by minimizing abnormal behaviors and improving physical condition.[3,4] However, gestation group housing enables aggressive interactions amongst females, particularly as they establish a group hierarchy and when they compete over restricted resources. This aggression occurs at the greatest intensity within the first 48 hours post mixing.[5,6] Aggression, which occurs most commonly during feeding can result in severe injuries.[7,8] The intensity and frequency of aggressive behavior can be influenced by many factors including age and experience, familiarity, and the feed system. For example, it has been reported that sows fed utilizing unguarded electronic sow feeders (ESF) display more aggressive behavior around the feeder when compared to conventionally group-housed sows fed using a trickle feeding system. This difference in aggressive behavior highlights the issue with sequential versus simultaneous feeding.[9] However, presenting a feed resource during the mixing of sows and throughout the initial establishment of a social hierarchy may not always be a cause for concern as it has been reported that mixing unfamiliar sows does not always increase the frequency of aggressive behaviors.[10,11] Additional factors that may affect sow aggressive behaviors in group-housing systems are space allowance and mixed-parity groups, where older and larger sows tend to be dominant over smaller gilts.[12,13] Whereas group size reportedly has little impact on aggression levels.[14-16]

Thus, increased understanding of swine aggression and pen dynamics in housing and feeding systems commonly used by the industry will provide additional insight for refinement and management improvements of current systems as well as for future implementation of new feeding and housing strategies. Therefore, the objective of the present study was to investigate the effect of a single-entry/exit ESF in small static group housing on behavior, productivity, and social rank of females during the first 48 hours post mixing over two consecutive gestation periods. The hypothesis was that the static pen and familiarity with the ESF across successive gestation periods would reduce aggression in early post-mixing of the second gestation period, resulting in fewer injuries within the group and improved gilt and sow production.

## Materials and methods

The research protocol was approved by The Ohio State University Institutional Animal Care and Use Committee.

### Animals and housing

The study was conducted at The Ohio State University Swine Research Facility between December 2015 and June 2016. Fifty-eight, Landrace × Yorkshire gilts (DNA Genetics, Columbus, Nebraska) with no previous group gestation housing experience were enrolled in the study at approximately day 35 of gestation. After the first gestation, all gilts were managed and housed similarly until day 35 of their second gestation period when they were moved back into group housing with their previous pen mates. Between gestation periods, 9 sows were unable to join their previous cohorts and were omitted from the study leaving 49 sows for the second gestation period. Throughout the study, the grouped sows were managed as three static cohorts (first gestation: cohort 1, n = 20; cohort 2, n = 18; cohort 3, n = 20; second gestation: cohort 1, n = 19; cohort 2, n = 13; cohort 3, n = 17) with approximately 42 days between each cohorts' initial establishment during their first gestation period. Gilt first-mating criteria were (1) a minimum age of 300 days, (2) experiencing the second estrus period or greater, and (3) a minimum body weight of 136 kg. Prior to the initiation of group housing, all females in both gestation periods were housed and mated in standard individual gestation stalls (1.28 m²; 2.14 × 0.60 m, length × width) with partially slatted concrete flooring (slat width = 15.24 cm and gap width = 2.54 cm) and maintained in stalls until pregnancy confirmation. Females were fed parity-specific diets in gestation and lactation, and diets were formulated to meet or exceed the National Research Council nutrient guidelines.[17] Electronic identification tags (Allflex, USA Inc, Dallas, Texas) for monitoring ESF usage and daily feed intake were placed in the ear of each female during the individual housing period prior to the study.

### Experimental housing and design

The group gestation-housing area was composed of 3 pens (6.8 × 5.5 × 1.1 m, length × width × height) retrofitted across a section of the facility that previously contained gestation stalls. Each pen (Figure 1) consisted of two areas of solid concrete flooring (Lying area [A], 5.5 × 1.1 × 1.1 m; and ESF[C], 5.5 × 3.3 × 1.1 m; length × width × height) and a middle section of slatted concrete flooring (Water access area [B], 5.5 × 2.4 × 0.9 m). Pen sides consisted of covered hard polyethylene side walls (height 1.1 m) mounted to steel posts surrounding solid concrete areas, and a 3.5 m steel-barred gate separating pens allowed for visual and nose-to-nose contact with females from other pens (height: 0.9 m; 0.1 m distance between bars).

Pens were fitted with one, single-animal, single-entry/exit ESF (Gestal 3G, Jyga Technologies, Greeley, Kansas) that was installed in area C of the pen (Figure 1). Females had free access to the ESF station throughout the day; however, between midnight and 2 AM,

**Figure 1:** Schematic of a former gestation stall area retrofitted to a pen equipped with an electronic sow feeder (ESF) and two dual-nipple water drinkers. The pen was designed to accommodate 15 to 20 sows. Pen zones were defined as (A) lying area, (B) water nipple, or (C) electronic sow feeder.
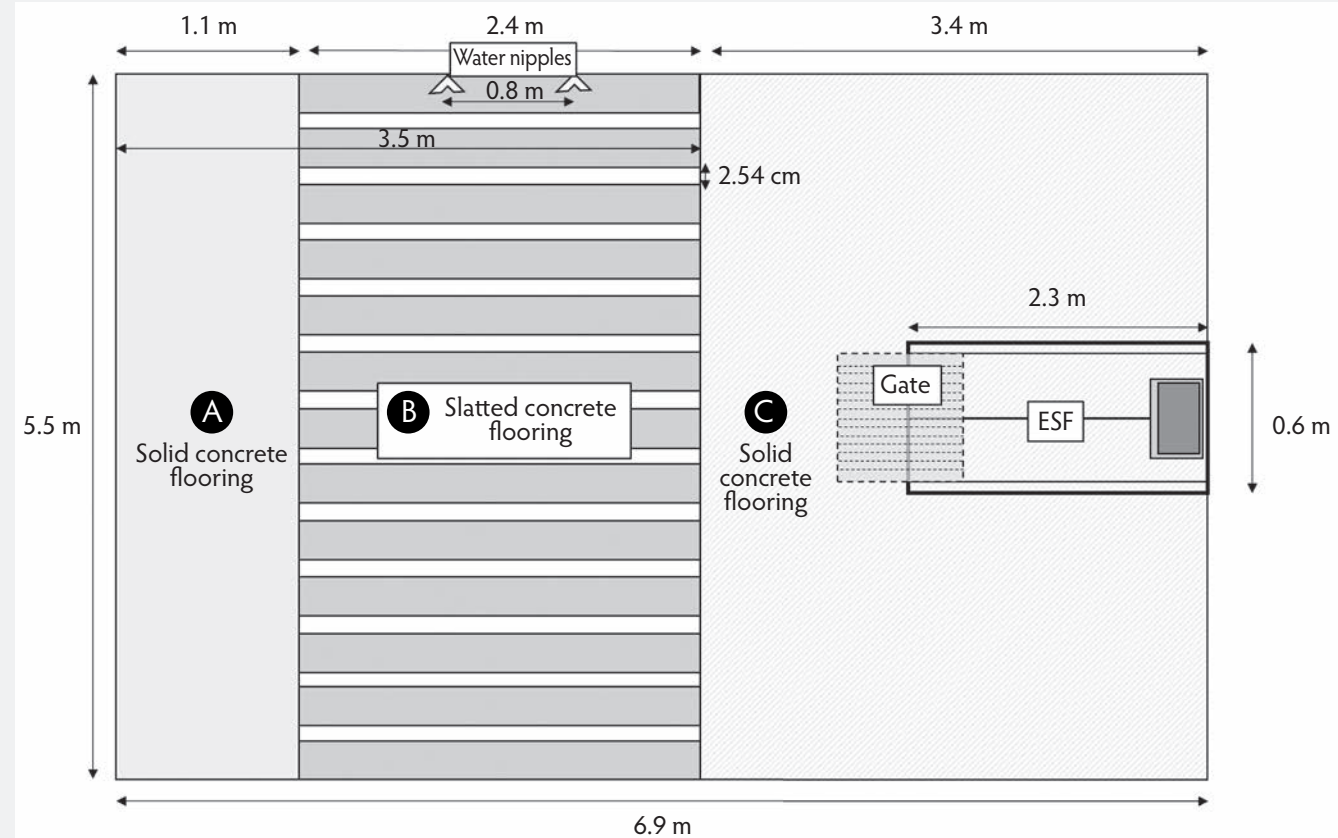


no feed was delivered. Feed disbursement occurred in 113 g per 30 second meals and feed was provided until the individual's daily allocation was delivered. Feed allocation required 8.0 and 10.6 min/female/d for first and second gestation periods respectively. Females were provided *ad libitum* access to water through two, twin-nipple drinkers (Edstrom Industries, Inc, Waterford, Wisconsin) located on one side of each pen above the slatted floor (Figure 1). The pen and ESF system were designed for a maximum group size of 20 females per feeding station and each female had 1.87 m² of space allowance.

## Data collection

To investigate behavioral changes over time, individual females were evaluated during parity 1 (gilts) and parity 2 (sows). Females were identified using a non-toxic animal identification paint (Marksman, Rumenco/Nettex, Staffordshire, United Kingdom) to place a unique number on the back and both flanks. All gilt and sow behaviors were recorded continuously over the first 48 hours post mixing by 1 color Internet Protocol (IP) based video camera (Model F19805P, 30 frames/sec, Wireless IP Camera; Foscam, Houston, Texas) attached at a height of 3 m overlooking each pen. Agonistic behaviors, including fights, were obtained exclusively as frequency data while all other behaviors were collected using duration and frequency data. Video recordings were analyzed by two observers using behavioral observation software (Noldus Observer XT 12, Wageningen, the Netherlands). To ensure inter-observer reliability, both observers were trained prior to initiation of data collection by scoring three, 2-hour segments of the video recordings and achieving at least 95% accuracy. The 2-hour segments were selected to capture all behaviors specified in the ethogram to assure that all observers were comfortable and accurate viewing the videos during the data collection. The selected time periods were the first 2 hours post mixing (08:00 to

10:00), behavior around the ESF and active feeding behavior (14:00 to 16:00), and night time behavior (22:00 to 00:00).

**Agonistic behavior.** The frequency of all initiated and received agonistic behavior (biting, chasing, and displacement) were recorded using continuous observation. The agonistic behaviors were registered as mutually exclusive, thus two behaviors could not occur at the same time. The frequency of all initiated and received agonistic behavior for each animal was recorded throughout the observed 48-hour period. For biting, every individually distinguishable bite was recorded. A chasing bout was defined as the time from when one sow was biting the hindquarter of another sow while running or running after another sow without any active biting until the initiating sow stopped running or switched focus to another sow. For displacement, the act of physically moving another pig from a resource or lying area would be counted as one bout. The frequency of agonistic behaviors targeted towards a specific body region (flank, head, or hindquarter)

**Table 1:** Definitions of sow behaviors used in analyses

| Behavioral category | Behavior | Definition |
|---|---|---|
| Active behavior | Standing | Standing up with at least 3 legs touching the floor. |
| | Walking | Walking or running in a forward or backwards direction. |
| Agonistic behavior | Biting flank | Biting at flank. |
| | Biting head | Biting on head or neck. |
| | Biting hindquarter | Biting on hindquarter or tail. |
| | Chasing | Actively following another sow while biting hindquarter or flank. |
| | Displacement | Removal of sow from ESF, water nipples, or lying area by actively biting the receiving sow's head, flank, or hindquarter. |
| | Fighting | Active reciprocal head to head biting between two sows until one of the sows stops the biting activity. |
| Inactive behavior | Lying | Lying sternally or laterally with sternum or side of the body touching the floor. |
| | Sitting | Sitting on hind legs with front legs touching the floor in front of body. |
| Maintenance behavior | Drinking | Actively drinking from the water nipple. |
| | Feeder visits | Walking into the ESF with entire body or with head in the feed bin. |
| | Feeding | Actively consuming feed in the ESF with head in the feed bin. |
| | Oral manipulation of ESF gate | Mouth or snout manipulating the ESF gate. |
| Other | Out of view | Pen mates blocking the focal sow from camera view. |

ESF = electronic sow feeder.

**Figure 2:** Social-rank index (RI) calculation adapted from Galindo and Broom[18] and the respective social-rank categories.

$$RI = \frac{\text{No. initiated agonistic bouts}}{\text{No. initiated agonistic bouts} + \text{No. received agonistic bouts}}$$

0    0.4    0.6    1

Low rank    Intermediate rank    High rank
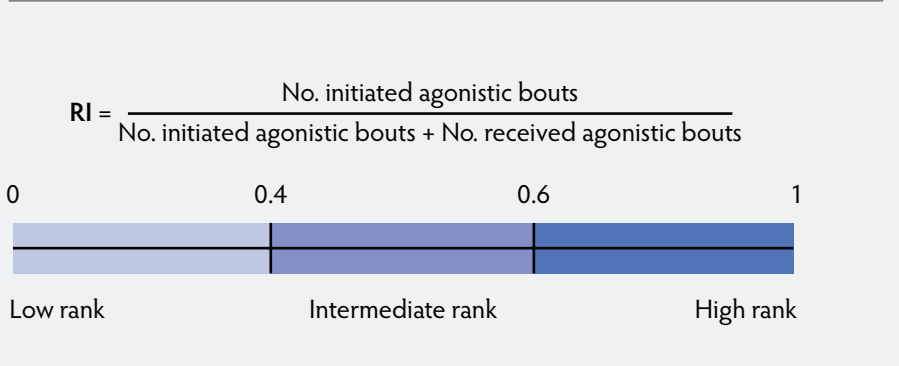
and occurring within a pen zone (Lying area [A], Water nipple [B], or ESF [C]; Figure 1) was recorded. A fight was defined as an active reciprocal head to head biting interaction between two sows until one of the sows stopped the biting activity or performed a different non-biting behavior. An ethogram of aggressive behaviors is found in Table 1.

**Social-rank index.** A social-rank index (RI) score was calculated for each individual animal by dividing the number of initiated agonistic bouts with the summed total of initiated and received agonistic bouts per individual over 48 hours (methodology adopted from Galindo and Broom;[18] Figure 2). The calculation yielded an RI score between 0 and 1 which was translated into 3 social-rank categories (high: RI ≥ 0.6; intermediate: 0.4 ≥ RI < 0.6; and low: RI < 0.4). Females in the high category initiated more aggressive bouts, whereas females in the low category received a greater number of aggressive bouts.

**General behavior.** The duration of feeding, drinking, lying, sitting, standing, and walking was recorded using continuous observation for each female by zone (Lying area [A], Water nipple [B] or ESF [C]). In addition, feeder visit frequency and duration and frequency of oral manipulation of the ESF gate was also recorded for each female within this 48-hour period.

**Production and animal care.** Litter traits recorded were the number of born alive, light weight pigs, mummified, nursed, stillborn, total born, and total weaned per litter. Piglet weight at weaning was collected, summed, and averaged within the litter. Female body weights were collected at the time of weaning. The daily feed intake and the feed intake for the total lactation period was recorded for each female. Daily observations of animal care were conducted per the farm's standard operating procedures and details of animal treatments, including duration and outcomes, were recorded.

**Treatments and removals.** Throughout the study, injuries or illness were reported and treated by farm staff in 13 of 58 (22.4%) females during the first gestation period and 8 of 49 (16.3%) females during the second gestation period. Reasons listed for treatment across both parity groups included musculoskeletal injury or lameness (n = 18; 85.7% of animals treated), "off feed" (n = 2), and thin body condition/diarrhea (n = 1). All treatments were administered per label directions according to the farm's standard operating procedures or under the direction of the attending veterinarian. Duration of treatment administration ranged from 1 to 8 consecutive days, with an average of 3.2 days in which the female was receiving treatment. Three females were humanely euthanized via penetrating captive bolt and 1 female died during the study, but none during the 48 hours post mixing. Reasons for euthanasia included a broken leg (n = 1), extremely poor body condition in conjunction with unresolving diarrhea (n = 1), and worsening lameness despite treatment (n = 1). One female died unexpectedly and was diagnosed with a ruptured mesenteric artery upon necropsy. Overall mortality rate was 6.9% (4 of 58 females) during the duration of the study. Females culled after completing their first parity were removed due to failure to return to estrus (n = 3), failure to conceive (n = 3), poor body condition at regrouping (n = 2), and failure to train to ESF (n = 1).

## Statistical analysis

Data were analyzed using SAS software (Version 9.4; SAS Institute Inc, Cary, North Carolina). Zones A and B (Lying area and Water) were merged for a more accurate comparison with zone C (ESF) based on zone area footprint within the pen (Figure 1). Lying and sitting behaviors were merged into an inactive category and standing and walking were merged into an active category, while feeding and drinking were analyzed as their own mutually exclusive behaviors. Additionally, all initiated flank, head, and hindquarter bites were merged into one biting category to be able to analyze the effect of social-rank on the pen zone where the most bites occurred. The normality of the data was assessed using the PROC univariate procedure and by evaluating residual plot distribution.

All behavior categories were considered not normally distributed and were therefore analyzed with a generalized linear mixed model (PROC GLIMMIX) using a Poisson distribution for frequency data. Fixed effects of parity (1 or 2), rank (high, intermediate, and low), body region (flank, head, or hindquarters), pen area (Lying area or ESF), and their interactions, with individual nested within pen as a random effect, were tested in the initial model. Non-significant interactions ($P > .20$) were removed from the final models. Contrast statements with a Bonferroni adjustment were used to identify statistical differences.

Measures of female productivity were analyzed using a generalized linear mixed model (PROC MIXED) with fixed effects of parity (1 or 2; ie, post hoc analysis after farrowing), rank (high, intermediate, and low), and their interactions, as well as using a random effect of static cohort group (1, 2, or 3) for initial models. Interaction effects were not significant ($P > .20$) for all measures and were removed from final models. A linear covariate for weaning age was used to adjust sow weight, feed intake, and litter weight measurements to a 21-day weaning age basis. Least squares means and standard errors were estimated and assessed using the PDIFF option in SAS.

Treatment and removals were reported as frequency and proportions within and across cohort and parity for explanation of changes in animal numbers between consecutive parities and to acknowledge measured characteristics of the population. No statistical analyses were performed.

## Results

### Agonistic behavior over gestation periods

A total of 6999 agonistic bouts were recorded for all females for both gestation periods (first gestation period, n = 5215; second gestation period, n = 1784), of which 6831 (97.6%) of these agonistics behaviors were biting bouts, 112 (1.6%) were displacement bouts, and 56 (0.8%) were chasing bouts.

**Figure 3:** Least squares means of biting bouts per sow by pen location and gestation period (first gestation period, n = 58; second gestation period, n = 49). Data was analyzed using a generalized linear mixed model (PROC GLIMMIX). An * indicates significant differences between gestation periods within the pen area ($P = .002$). ESF = electronic sow feeder.
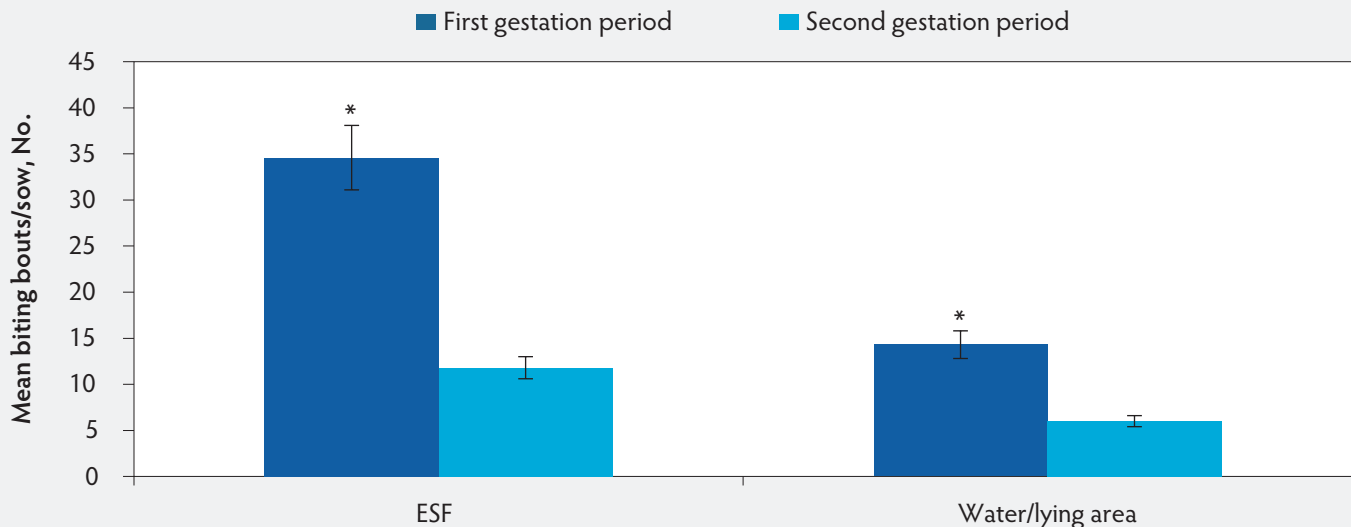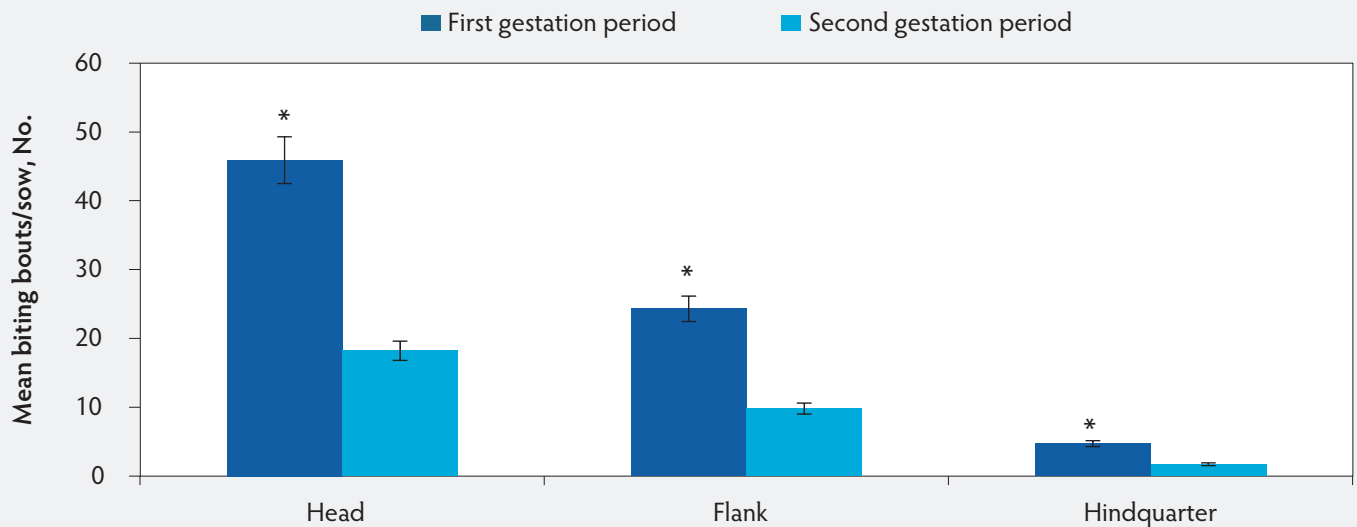
**Figure 4:** Least squares means of biting bouts per sow by body location and gestation period (first gestation period, n = 58; second gestation period, n = 49). Data was analyzed using a generalized linear mixed model (PROC GLIMMIX). An * indicates significant differences between gestation periods within a body location ($P < .001$).



The total number of initiated biting bouts decreased between the first and second gestation period (mean [SE]; 20.8 [2.1] vs 7.7 [0.8] bouts/female; $F_{1,145} = 554.75$, $P < .001$). Additionally, the number of biting bouts decreased in both the water/lying area and around the ESF between the first and second gestation period (Figure 3; $F_{1,151} = 9.74$, $P = .002$). The most targeted body area was the head region followed by the flank and hindquarter of the sow regardless of gestation period (Figure 4, $F_{2,256} = 827.63$, $P < .001$). The number of fights were more frequent during the first gestation period when compared to the second gestation period (mean [SE]; 2.1 [0.3] vs 1.1 [0.2] fights/female; $F_{1,145} = 22.31$, $P < .001$) and more frequent in the ESF area compared to the water/lying area regardless of gestation period (mean [SE]; 3.5 [0.3] vs 0.7 [0.2] fights/female; $F_{1,145} = 177.90$, $P < .001$). The number of displacements were infrequent and did not differ between gestation periods (mean [SE]; 0.38 [0.1] vs 0.23 [0.1] bouts/female; $F_{1,145} = 0.20$, $P = .65$), but more displacements were performed around the ESF when compared to the water/lying area within the pen (mean [SE]; 0.41 [0.1] vs 0.22 [0.1] bouts/female; $F_{1,145} = 7.53$, $P = .007$). Chasing bouts were infrequent but a greater number tended to occur during the first gestation period when compared to the second gestation period (mean [SE]; 0.15 [0.05] vs 0.06 [0.02] bouts/female; $F_{1,145} = 2.88$, $P = .06$) while no difference was observed between the ESF and the water/lying area (mean [SE]; 0.16 [0.05] vs 0.07 [0.03] bouts/female; $F_{1,145} = 0.56$, $P = .46$).

**Figure 5:** Least squares means of biting bouts per sow across both gestation periods by pen location and sow social rank (high, n = 23, intermediate, n = 42, low, n = 42). Data was analyzed using a generalized linear mixed model (PROC GLIMMIX). Different letters indicate significant differences ($P < .001$). ESF = electronic sow feeder.
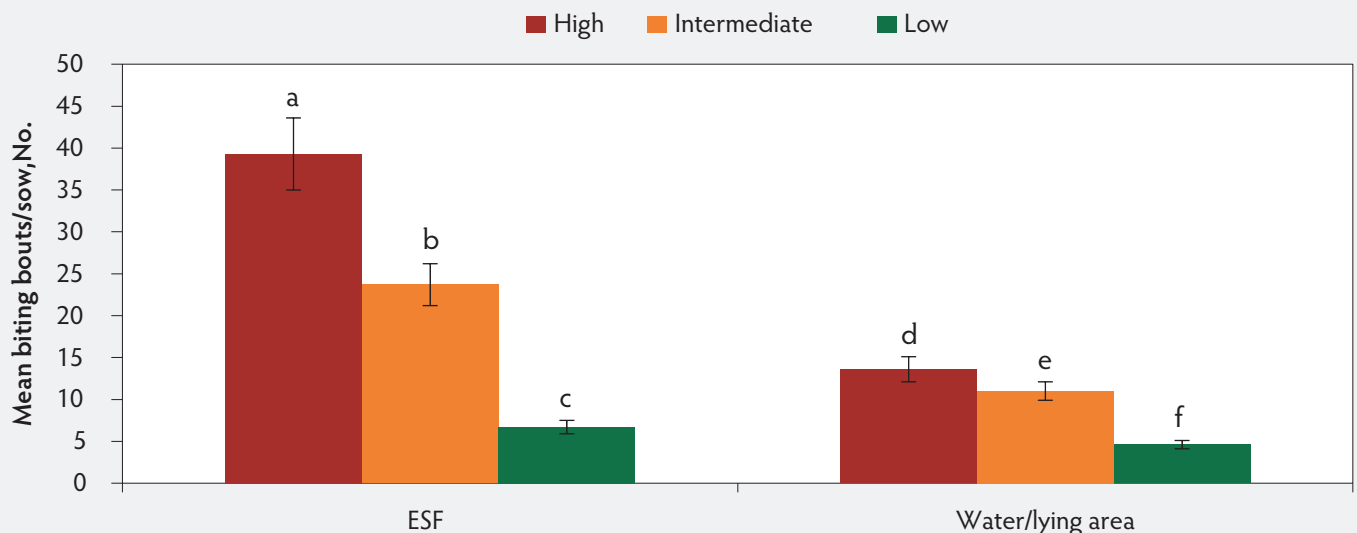
## Agonistic behavior and social rank

The social-rank scores shifted between the first (of the 58 females, 9 [15.5%] ranked high, 28 [48.3%] ranked intermediate, and 21 [36.2%] ranked low) and second gestation period (of the 49 females, 15 [30.6%] ranked high, 13 [26.5%] ranked intermediate, and 21 [42.8%] ranked low). A social rank × pen zone interaction was significant with high-ranked sows initiating a greater number of biting bouts around the ESF when compared to intermediate- and low-ranked females. High-ranked females initiated the most biting bouts, followed by intermediate-ranked females and lastly low-ranked females for both ESF area and water/lying area (Figure 5; $F_{2,145} = 26.21$, $P < .001$).

High- and intermediate-ranked females performed a greater number of fights when compared to low-ranked females during the first gestation period (mean [SE]; 2.3 [0.8], 2.1 [0.4], and 0.8 [0.2] fights/female for high-, intermediate-, and low-ranked females, respectively; $F_{2,145} = 15.42$, $P < .001$).

A tendency in the number of displacements between social rankings was observed with intermediate-ranked females more frequently displacing high- and low-ranked females (mean [SE]; 0.17 [0.1], 0.42 [0.1], and 0.21 [0.1] displacements/female for high-, intermediate-, and low-ranked females, respectively; $F_{2,145} = 2.95$, $P = .06$). Similarly, a tendency in the number of chasing events between social rankings was observed with high- and intermediate-ranked females more frequently chasing low-ranked females (mean [SE]; 0.18 [0.1], 0.20 [0.1], and 0.04 [0.03] bouts/female for high-, intermediate-, and low-ranking females, respectively; $F_{2,145} = 2.88$, $P = .06$).

## General behavior

The time spent active did not differ between gestation periods (mean [SE]; 167.03 [8.38] vs 159.17 [8.3] min/female; $F_{1,145} = 0.51$, $P = .47$). Overall, most active behaviors were observed around the ESF when compared to the water/lying area (mean [SE]; 243.9 [8.2] vs 82.3 [8.2] min/female; $F_{1,145} = 232.37$, $P < .001$). No difference in the time spent inactive was observed between gestation periods (mean [SE]; 911.0 [66] vs 905.2 [64] min/female; $F_{1,141} = 0.01$, $P = .95$). Females also spent the most time inactive around the ESF when compared to the water/lying area (mean [SE]; 1258.2 [63.3] vs 557.9 [64.0] min/female; $F_{1,141} = 62.27$, $P < .001$). Total

time spent in the feeding station (mean [SE]; 84.4 [7.4] vs 112.8 [7.1] min/female; $F_{1,97} = 7.41$, $P = .008$) and the number of feeder visits (6.5 [0.7] vs 8.7 [0.8] visits/female; $F_{1,103} = 3.89$, $P = .05$) increased during the second gestation period when compared to the first gestation period. The length of feeder visits did not increase between the first and second gestation period (mean [SE]; 13.5 [1.3] vs 15.8 [1.3] minutes per female per feeding bout, $F_{1,103} = 1.43$, $P = .23$). No other significant results were found.

## General behavior and social rank

Female social rank and gestation period did not affect time spent performing active behaviors (mean [SE] per female; First gestation period: 378.4 [48.6], 406.2 [27.5], and 440.8 [31.8]; Second gestation period: 407.9 [39.0], 381.3 [39.0], and 431.4 [31.8] min/d for high-, intermediate-, and low-ranked females, respectively; $F_{2,101} = 0.24$, $P = .78$) or inactive behaviors (First gestation period: 2312.2 [62.6], 2291.5 [35.5], and 2251.6 [40.0]; Second gestation period: 2313.5 [50.2], 2365.9 [50.2], and 2304.1 [41.0] min/d for high-, intermediate-, and low-ranked females, respectively; $F_{2,101} = 0.26$, $P = .76$).

High-ranked females visited the feeder more frequently when compared to intermediate- and low-ranked females during the first gestation period (mean [SE]; 7.5 [1.1], 6.2 [0.7], and 6.1 [0.8] bouts per female per 48 hours for high-, intermediate-, and low-ranked females, respectively, $F_{2,256} = 8.47$, $P < .001$) but high- and intermediate-ranked females visited the feeder less frequently compared to low-ranked females during the second gestation period (7.5 [0.8], 7.8 [0.9], and 10.1 [0.8] bouts per female per 48 hours for high-, intermediate-, and low-ranked females, respectively; $F_{2,256} = 8.47$, $P < .001$). High-ranked sows spent less time feeding compared to low-ranked sows with intermediate-ranked sows not differing from other sows during the first gestation period (mean [SE]; 10.2 [1.9], 16.2 [1.2], and 12.4 [1.3] min/visit for high-, intermediate-, and low-ranked females, respectively; $F_{2,256} = 3.15$, $P = .04$) but no difference was seen during the second gestation period (16.2 [1.5], 15.8 [1.5], and 16.0 [1.3] min/visit for high-, intermediate-, and low-ranked females, respectively; $F_{2,256} = 0.28$, $P = .81$). No difference in total feeding time between social-rank categories

was found (mean [SE]; 97.5 [10.4], 92.1 [8.4], and 106.6 [8.0] min/48h, for high-, intermediate-, and low-ranked females, respectively; $F_{2,95} = 0.83$, $P = .43$). High- and intermediate-ranked females spent more time manipulating the ESF gate when compared to low-ranked females (mean [SE]; 46.2 [6.5], 25.6 [5.0], and 13.5 [5.0] min/48h, high-, intermediate-, and low-ranked females, respectively; $F_{2,100} = 7.69$, $P < .001$) but no female social rank × gestation period interaction was observed ($F_{2,100} = 2.06$, $P = .13$).

High-ranked females spent the most time drinking followed by intermediate-ranked females, while low-ranked females spent the least amount of time drinking (mean [SE]; 17.6 [2.0], 12.0 [1.5], and 10.0 [1.5] minutes per female per 48 hours; $F_{2,101} = 6.84$, $P < .01$). No female social rank × gestation period interaction was observed ($F_{2,101} = 0.97$, $P = .38$).

## Production

Performance measures for the commercial females evaluated in the present study were indicative of highly prolific, strong maternal genetic resources. No differences in litter and female productivity measures (Table 2) were observed when comparing social rank categories in the present study, a strong indication that, while females clearly demonstrated hierarchy differences early following mixing, the implanted fetuses survived and female productivity was maintained equally across aggression categories through the first and second lactations. Parity effects were present as expected, with parity 2 females producing a greater number of total piglets born (mean [SED]; 2.12 [0.69] piglets; $F_{1,95} = 9.25$, $P < .001$), piglets born alive (1.85 [0.71] piglets; $F_{1,95} = 6.83$, $P < .001$), weaned piglets per litter (1.22 [0.28] piglets; $F_{1,95} = 19.28$, $P < .001$), and litter weight (6.39 [6.26] kg; $F_{1,95} = 7.90$, $P < .001$) when compared with parity 1 females.

## Discussion

### Behavior during the first 48 hours post mixing

Primary challenges with group-housed gestating females are the provision of a feeding system that can provide control over an individual female's feed intake and the implementation of methods or approaches that reduce aggression caused by mixing and resource guarding. Despite reports of

**Table 2:** Least squares means for female and litter performance measures by social rank across first and second gestation period*

| | Social rank[†] | | | SE | F Value | P Value[‡] |
| --- | --- | --- | --- | --- | --- | --- |
| | **High** | **Intermediate** | **Low** | | | |
| **Female traits[§]** | | | | | | |
| Average daily feed intake, kg | 6.2 | 6.1 | 6.5 | 0.4 | $F_{2,95} = 1.80$ | .17 |
| Total lactation feed intake, kg | 139.4 | 139.9 | 145.8 | 8.4 | $F_{2,95} = 1.13$ | .33 |
| Weight at weaning, kg | 202.0 | 205.1 | 205.2 | 5.4 | $F_{2,95} = 0.35$ | .70 |
| **Litter traits** | | | | | | |
| Light weight pigs (< 0.68 kg), No. | 0.21 | 0.23 | 0.33 | 0.11 | $F_{2,95} = 0.34$ | .72 |
| Litter weaning weight, kg | 78.6 | 78.1 | 82.6 | 2.96 | $F_{2,92} = 1.78$ | .18 |
| Mummies, No. | 0.46 | 0.43 | 0.40 | 0.19 | $F_{2,95} = 0.16$ | .86 |
| Piglets born alive, No. | 14.23 | 14.83 | 14.59 | 0.73 | $F_{2,95} = 0.21$ | .80 |
| Piglets nursed, No. | 13.54 | 13.94 | 13.71 | 0.34 | $F_{2,95} = 0.82$ | .44 |
| Piglets weaned, No. | 12.69 | 12.62 | 12.89 | 0.38 | $F_{2,95} = 0.39$ | .85 |
| Piglet weaning weight, kg | 6.24 | 6.22 | 6.45 | 0.13 | $F_{2,92} = 1.03$ | .36 |
| Stillborn piglets, No. | 1.74 | 1.23 | 1.01 | 0.25 | $F_{2,95} = 2.02$ | .14 |
| Total piglets born, No. | 16.42 | 16.14 | 15.89 | 0.72 | $F_{2,95} = 0.17$ | .85 |

* Information provided for both gestation periods (first gestation period, n = 58; second gestation period, n = 49).
† A social-rank index score was calculated for each individual animal by dividing the number of initiated agonistic bouts with the summed total of initiated and received agonistic bouts per individual over 48 hours. The calculation yielded an index score which was categorized to high (≥ 0.6), intermediate (≥ 0.4 and < 0.6), and low (< 0.4).
‡ All female and litter traits were analyzed using a generalized linear mixed model (PROC MIXED) with fixed effects of parity (1 or 2; ie, post hoc analysis after farrowing), rank (high, intermediate, and low), and their interactions, and static cohort group (1, 2, or 3) as a random effect. Significance was treated as $P < .05$.
§ Measures adjusted to a 21-day weaning age.

increased aggression around unguarded ESF stations when compared to trickle feeding or free access stalls,[9] the consistent upgrades in technology and system design contributes to ESF stations now being a commonly chosen gestation feeding system.[19,20] In addition, commercial entities have established that utilizing static grouping strategies can help alleviate aggression levels for the entire group-housed gestation period, depending upon total space allocation provided. In the present study, agonistic behavior levels during the first 48 hours in group gestation housing were reduced by approximately 60% and the number of fights were reduced by approximately

40% between the first gestation period, when sows were unfamiliar with their pen mates, and the second gestation period, when sows were housed back together with their previous pen mates. These results coincide with two earlier studies that reported lower levels of aggression when sows were familiar with each other in either group housing[20] or when housing pigs temporarily in pairs to quantify agonistic behaviors.[21] Thus, it is reasonable to ascertain that a key factor influencing the reduced aggression observed in this study was pen-mate familiarity as reported by contemporary studies.[22,23] However, familiarity should not be interpreted as the sole

contributing factor to the observed reduced aggression as age and experience are likely to affect aggression levels in group housed sows.[11] Results from the present study are in contrast to studies that reported no difference in the level of aggression in sows during a 2- or 8-hour observation window post mixing in either small or large groups.[16,24] Furthermore, a recent large-scale study reported no effect of group size on sow aggression, suggesting that a large number of sows may be housed together without increased aggression levels.[15] The lack of aggression in larger groups observed by Hemsworth et al[15] could potentially be due to the disruption or change of displayed

dominance behavior due to a large number of competitors.[25] The present study, by design, kept a targeted group size of 20 females to accommodate the ESF feeding system design capacity. In contrast, other commercially available ESF systems can accommodate access for 60 to 80 animals per group depending on ESF design and management. Considering larger group sizes require either multiple stations with single-animal entry/exit or a pass-through station design that allows females to leave the ESF on the opposite side from where the next female in line will attempt to enter, the present study findings represent data most comparable to small-scale production systems using small group sizes during gestation.

In the present study, most aggression was reported near and around the ESF when compared to the water/lying area, a finding that identifies feed as a valued resource. In addition, being a single-entry/exit ESF design, it is likely that a greater level of aggression may occur as antagonists have more opportunities to attack entering and exiting females compared to an ESF with a pass-through design. It is possible that having an additional single-entry/exit ESF or having a separate exit, or pass-through ESF, may have decreased aggression levels. Additionally, it was not feasible to implement a pass-through ESF system in the small, retro-fitted, group pens used in this study due to cost and the physical footprint required.

The greater number of initiated agonistic bouts around the ESF by high-ranked females when compared to lower-ranked females may be due to resource-based guarding given the value and motivation of feed for a limit-fed gestating female. Furthermore, the single-entry, backward-exit station design of the ESF may have allowed higher-ranking females to attempt to deny entrance of other individuals to the feeder by engaging in agonistic behaviors and impede or antagonize lower-ranked females as they were backing out of the ESF system after feeding. High-ranked females chased and displaced lower-ranked females which corresponds with previous knowledge regarding social relationships in swine and their interactions around resources within a pen.[26,27] Thus, the overall level of aggression cannot be solely interpreted as an effect of the hierarchy establishment within the group, but rather a combination of rank and resource guarding for feed. However, ESFs in combination with static groups

may be a better option compared to mixed groups as previous pen-mate familiarity could potentially reduce overall aggression normally occurring at mixing.

There was no difference in activity or inactivity levels between gestation periods, but females spent more time overall in close proximity to the ESF when compared to the other pen zones. Inactive behaviors were greater in this study (85% of the daily time budget for the 48-hour period) compared to previously reported research in group housing (66%-73%), stall systems (63%-84%),[28] or outdoor housing (78%).[28-31] It is likely that the lack of enrichments in the current study had an impact on the sows' time budgets resulting in a higher degree of inactivity as there was less opportunity to perform a wide range of active behaviors. It is also possible that exhaustion due to fighting or inability to rest due to the initial social unrest in the pen may have contributed to higher inactivity levels as sows may have overcompensated once aggression levels decreased. This suggests that during the 48-hour period, the female's behavioral repertoire is focused on fighting or resting with the females performing little to no exploratory behavior. No effect of social rank on activity was found suggesting that high-ranked sows interacted and possibly kept intermediate- and low-ranked sows alert and on their feet to avoid confrontation. This result is in contrast with an earlier study showing low-ranked sows being more inactive compared to their high-ranked pen mates.[32]

As expected, the total feeding time and feeder visit length increased during the second gestation period as the females returning were older heavier animals with greater maintenance nutritional demands and previous ESF experience. Time spent feeding in the present study (2%-4% of daily time budget; 42-55 min/d) was greater when compared to earlier work with group gestation housing with other types of ESF units (eg, 31 min/d for unspecified ESF unit;[29] 22 min/d for unprotected ESF - Fitmix[33]). Differences in results from the present study are likely due to the feed drop rate (113 g per 30 seconds) or total feed delivered which may have increased the time spent in the feeder to get the entire meal delivered and consumed. However, no difference in feeding time was seen between sow social rankings. Furthermore, the enclosed design of the ESF protected females from being displaced from the feeder prematurely, thus allowing

for an uninterrupted and sequentially slower feeding rate compared to unprotected feeding systems. It is possible that high-ranked sows may have been able to get access to the feeder more often simply by entering more frequently to search for leftover feed from the previous sow. Although high-ranked females visited the feeder more frequently when compared to intermediate- and low-ranked females during the first gestation period, low-ranked sows had the longest feeder visit on average. Additionally, low-ranked females had a larger number of feeder visits when compared to high- and intermediate-ranked females during the second gestation period making it hard to interpret the change in visit frequency between high- and low-ranked sows. A possible explanation is that the high-ranked females defended what would be regarded as the high-value resource in the pen during the first gestation period preventing or reducing the frequency of visits in low-ranked females. An indication that supports this explanation is that most agonistic bouts were recorded around the ESF, a finding supported by previous studies[4,34,35] as well as the larger amount of time spent at the water nipples by high-ranking sows in the current study. Moreover, it is possible that vocal threats or postural threats (variables not recorded in this study) by high-ranked females could have forced low-ranked females out of the ESF without any physical contact. Physical contact was a requirement in the definition of displacement, therefore any vocal or postural threat-based displacement was not assessed.

## Production

No overall differences in female performance or litter traits were observed between social rank categories, a finding that is in contrast to two earlier studies that reported a relationship between high-ranking females and heavier offspring body weight at birth and weaning.[32,36] No differences were noted in total piglets born alive between gestation periods, a result supported by earlier findings that did not report any differences in total piglets born alive between dynamic and static groups during gestation[33] or housing effects on live litter sizes at birth and weaning when comparing gestation stalls or small and large group pens.[37] However, results from the current study are in contrast to a recent study that reported fewer piglets born alive from high-ranked females when compared to low-ranked females, with intermediate-ranked females in between.[38] Verdon et al[11] found that high-ranking females had increased cor-

tisol levels (a parameter not measured in the present study) due to increased aggression from remixing. It was speculated that the increased cortisol resulted in greater oxidative stress, which in turn could have contributed to a decrease in litter size, although this remains unclear. No difference in total piglets born was seen between social-rank categories, a result supported by recent studies.[11,39]

Parity influences on productivity measures were as expected in commercial production with the second parity litter size increasing, litter and piglet weight increasing, and female weight increasing with maturation. The combination of the female maturing physiologically and immunologically leads to a greater number of eggs ovulated, fertilized, and fully developed into live piglets[40] and improved colostrum quality and milk production, which lead to heavier, healthier piglets at weaning.[41,42]

## Conclusions

The results from this exploratory study showed that aggression decreased between the first and second gestation period during the initial 48 hours when sows were in static group housing with a gated ESF. The outcome is likely to be linked to familiarity with previous pen mates, even with individual housing during lactation and post weaning through confirmation of pregnancy, but age and experience may also play a significant role. The use of a gated single-entry/exit ESF ensured that all animals received their daily feed allocation and performed at industry expected levels, but also resulted in aggression near the feeder due to resource guarding. In situations where housing style is dictated by regulation or where new or retrofit construction options are being considered, the single-entry/exit ESF system can be considered. Additional research to alleviate agonistic behaviors in group-housed females, particularly early post mixing, is still warranted to continue to improve individual pig welfare.

## Implications

- Small, static, sow groups in gestation decreases aggression between first and second parity during the first 48 hours post mixing.
- Electronic sow feeder systems tailored for small-group gestation housing presents an alternative for sow barns that are being converted.

## Acknowledgements

## Conflict of interest

None reported.

## Disclaimer

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# Presence of Senecavirus A in pork sold in the United States

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## Summary

**Objective:** To estimate the prevalence and concentration of Senecavirus A (SVA) in meat sold at retail.

**Materials and methods**: A total of 190 meat samples derived from 25 processing locations in 13 states were purchased through retail sources. The presence of virus in samples of muscle obtained from each package was assessed by polymerase chain reaction (PCR) amplification of SVA nucleic acid. A standard curve was constructed to estimate the concentration of viable virus in PCR-positive samples.

**Results:** Two of the 190 meat samples (1.1%) were positive for SVA nucleic acid, but negative for virus by virus isolation. The amount of virus in the PCR-positive samples was estimated to be less than 14 virions/g of muscle.

**Implications:** The low prevalence of SVA in the 190 retail-meat samples analyzed in this study, combined with a low concentration of SVA nucleic acid in the two SVA-positive samples, suggest a low risk for transmitting SVA through retail meat.

**Keywords:** swine, Senecavirus A, SVA, SVA in meat

## Resumen – Presencia del Senecavirus A en cerdo vendida en los Estados Unidos

**Objetivo:** Estimar la prevalencia y concentración del Senecavirus A (SVA por sus siglas en inglés) en carne vendida al menudeo.

**Materiales y métodos:** Un total de 190 muestras de carne procedente de 25 sitios de procesamiento en 13 estados fueron compradas a través de fuentes de venta al menudeo. La presencia del virus en muestras de músculo obtenidas de cada paquete fue evaluada por medio de la amplificación de la reacción en cadena de polimerasa (PCR por sus siglas en inglés) del ácido nucleico del SVA. Se elaboró una curva estándar para estimar la concentración de virus viable en muestras positivas al PCR.

**Resultados:** Dos de las 190 muestras de carne (1.1%) resultaron positivas al ácido nucleico del SVA, pero resultaron negativas al virus por medio de aislamiento viral. Se estimó que la cantidad de virus en las muestras positivas al PCR era menos de 14 viriones/g de músculo.

**Implicaciones:** La baja prevalencia de SVA en las 190 muestras de carne vendida al menudeo analizadas en este estudio, en conjunto con la baja concentración de ácido nucleico SVA en las dos muestras positivas al SVA, sugieren un bajo riesgo de transmisión del SVA por medio de la carne vendida al menudeo.

## Résumé – Présence du Senecavirus A dans le porc vendue aux États-Unis

**Objectif:** Estimer la prévalence et la concentration de Senecavirus A (SVA) dans la viande vendue au détail.

**Matériels et méthodes:** Un total de 190 échantillons de viande obtenu de 25 usines de transformation dans 13 états furent achetés dans des magasins de vente au détail. La présence du virus dans des échantillons de muscle obtenus de chaque emballage était déterminée par réaction d'amplification en chaine par la polymérase (PCR) de l'acide nucléique du SVA. Une courbe standard fut élaborée pour estimer la concentration de virus viables dans les échantillons positifs par PCR.

**Résultats:** Deux des 190 échantillons de viande (1.1 %) étaient positifs pour l'acide nucléique de SVA, mais négatifs pour l'isolement viral. On estima à moins de 14 virions/g de muscle la quantité de virus dans les échantillons positifs par PCR.

**Implications:** La faible prévalence de SVA dans les 190 échantillons de viande analysés dans la présente étude, ainsi que la faible concentration d'acide nucléique de SVA dans les deux échantillons positifs, suggèrent un faible risque de transmission de SVA via la viande vendue au détail.

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Senecavirus A (SVA), also known as Seneca Valley virus, is a single-strand, non-enveloped RNA virus belonging to the genus *Senecavirus,* family Picornaviridae.[1,2] Important foreign animal disease (FAD) viruses in this family include foot-and-mouth disease virus (FMDV) and swine vesicular disease virus (SVDV). Similarities with FMDV in terms of physiochemical properties make SVA a suitable surrogate for understanding the environmental stability of FMDV.[3] The key clinical sign associated with FMDV or SVDV infection of pigs is the formation of vesicular lesions on the snout and feet.[4] In 2004, an outbreak of idiopathic vesicular disease occurred in a farrow-to-finish farm in Indiana.[5] Extensive analysis showed that pigs were negative for FMDV, SVDV, and other agents associated with vesicular lesions. The infected pigs eventually recovered, but vesicular disease signs reappeared in the herd. Pasma et al[6] identified SVA as the source of the vesicular disease syndrome. The virus possessed a nucleic acid sequence closely related to a virus originally isolated in Brazil.[7-9] Experimental infection studies confirmed the ability of SVA to cause vesicular lesions.[10] However, it should be noted that SVA can be present in pigs without signs of overt clinical disease.

Perhaps the greatest impacts of SVA infection on swine production are the consequences of finding vesicular lesions. Because vesicular lesions are associated with FMDV and SVDV, the appearance of lesions results in herd closure followed by time-consuming FAD investigations involving local, state and federal authorities.

It is well established that pig meat is a potential vector for introducing disease into naïve populations.[11] For meat to be a risk for infection, the virus must be present in a sufficiently high quantity to deliver an infectious oral dose to a susceptible animal. A likely mechanism for disease introduction is via uncooked meat scraps or spoiled meat discarded as garbage. Infection could occur through the consumption of the discarded meat by feral pigs, which then could come into contact with domestic pigs. Another route for introduction is through the incorporation of meat scraps into unprocessed swill fed to backyard pigs.

The purpose of this study was to investigate the potential risk of introducing SVA through meat by estimating the prevalence and concentration of SVA nucleic acid in muscle meats purchased at retail. Because the time from slaughter to purchase of a pork product in a retail store within the United States is similar to the time needed to transport pork to another country via legal trade, and because the steps and processes involved are also comparable, the condition and age of US pork products for sale at retail in the United States and other countries is also similar. Determining the current prevalence of SVA in retail products in the United States can subsequently aid in risk analyses surrounding SVA in pork.

## Materials and methods

### Collection and processing of retail meat samples

There are a limited number of studies that provide an estimation of the prevalence of SVA infection at the time of slaughter. Based on Hause et al,[9] we selected a prevalence of 1% to 5%, which is a conservative estimate. We would expect that the assay of 200 meat samples would yield 2 to 9 positive results. Of the 200 samples, 190 were successfully assayed. The ten samples not assayed consisted of products containing chopped or ground pork or were subjected to processing (ie, smoking, curing, or marinating). Sampling bias was avoided by selecting a variety

of cuts from six different retail supermarket chains located in Manhattan (five individual stores), Junction City (three stores), and Kansas City, Kansas (one store) and Alexandria, Virginia (one store). Sampling occurred on 15 days over a 2-month period between February 28, 2017 and April 30, 2017. Meat was collected from one to five stores per day. Based on establishment code numbers (ESTN), the origin of each package was traced to 1 of 25 meat processing locations in 13 states (Table 1). Effort was made to select packages that possessed unique ESTN to ensure that samples were collected from the greatest number of meat processing facilities. Ten facilities were in the Midwest: Colorado, Iowa, Illinois, Kentucky, Minnesota, Missouri, Nebraska, South Dakota, Texas, and Wisconsin. The remaining processing facilities were in California, North Carolina, and Virginia. Muscle meat samples with and without bone were analyzed including chops (41 samples), loins (61 samples), ribs (53 samples), roasts (9 samples), shoulders (18 samples), and other (8 samples). Less common cuts sampled, such as feet, carnitas (chopped meat), neck bones, and cutlets, were identified as other. Ground products, such as ground pork and fresh sausage, were

not part of this study, primarily because these products contain more than muscle meat and are generally not exported.

Refrigerated packages of meat were purchased at retail outlets and remained refrigerated until sample collection. Prior to sampling each package, all work surfaces and utensils were cleaned with 2% sodium hypochlorite (bleach) and thoroughly rinsed. Parchment paper was placed on the cleaned cutting surface. The exterior of each package was wiped down with bleach, assigned a unique identifier, and photographed to provide a record of product information and ESTN identifying the processing location. While wearing disposable gloves, a decontaminated knife or scissors was used to open the meat package. Using a fresh, decontaminated knife, a 5 to 10 g sample was excised, immediately placed in a plastic bag, and stored at -20°C until further processing to isolate RNA, typically within 48 hours. Between each sample collection, all utensils were soaked in bleach and thoroughly rinsed, surfaces were cleaned with bleach, and disposable gloves and surface parchment paper replaced.

**Table 1:** Sampled cuts of meat and the processing establishment location from which they originated

| State (No.*) | chop | loin | rib | roast | shoulder | other† | Total |
|---|---|---|---|---|---|---|---|
| CA (1) | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| CO (1) | 19 | 3 | 7 | 0 | 3 | 1 | 33 |
| IA (5) | 0 | 3 | 7 | 0 | 0 | 0 | 10 |
| IL (2) | 0 | 8 | 3 | 0 | 0 | 0 | 11 |
| KY (1) | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| MN (5) | 0 | 12 | 9 | 1 | 0 | 0 | 22 |
| MO (2) | 8 | 4 | 6 | 3 | 0 | 0 | 21 |
| NC (2) | 0 | 0 | 4 | 0 | 0 | 0 | 4 |
| NE (2) | 3 | 16 | 8 | 0 | 8 | 1 | 36 |
| SD (1) | 0 | 10 | 4 | 5 | 4 | 0 | 23 |
| TX (1) | 10 | 2 | 4 | 0 | 2 | 6 | 24 |
| VA (1) | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| WI (1) | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| **Total** | **41** | **61** | **53** | **9** | **18** | **8** | **190** |

\* Number of processing establishments in each state represented in the sample.
† Less common cuts sampled, such as feet, carnitas (chopped meat), neck bones, and cutlets, were identified as other. Ground products, such as ground pork and fresh sausage, were not part of this study.

## RNA isolation and polymerase chain reaction of SVA nucleic acid

For isolation of total RNA, a 200 mg sample of muscle was placed in a GentleMACS M Tube. Four milliliters of TRIzol Reagent (Invitrogen, Waltham, Massachusetts) was added and the sample homogenized on a GentleMACS (Miltenyi Biotec, Auburn, California) for 84 seconds. Insoluble material was removed by centrifugation at 10,000$g$ for 5 minutes. A 1-mL sample of supernatant was divided between two 1.5-mL microcentrifuge tubes and 0.5 mL of ethanol added to each tube. The RNA was isolated using a Directzol RNA MiniPrep Kit (R2052, Zymo Research, Irvine, California) according to the kit instructions. The RNA was eluted in a final volume of 50 μL of nuclease-free water and stored at -80°C. Polymerase chain reaction (PCR) was performed using the EZ-SVA Real Time RT-PCR detection kit (Tetracore, Rockville, Maryland). Briefly, a 25 μL reaction was carried out using 7 μL of extracted RNA and all steps performed according to the manufacturer's instructions. Reverse transcription and amplification were performed on a CFX96 C1000 Thermal Cycler (BioRad, Hercules, California) under the following conditions: reverse transcription at 48°C for 15 minutes, initial denaturation at 95°C for 2 minutes, followed by 45 cycles of 95°C for 5 seconds and 60°C for 40 seconds. The high specificity of the commercial assay is based on the unique sequence of the primers specific for the SVA genomic sequence along with optimal PCR conditions used for amplification. This assay does not cross-react with other swine viruses. In terms of false-positive rates, the manufacture recommends that cycle threshold (Ct) values between 38 and 40 be retested.

## Preparation of SVA standard curve

The sensitivity of the assay was determined by preparing a standard curve utilizing the SVA laboratory strain, KS15-01, which was originally isolated from a pig nasal swab sample by the Kansas Veterinary Diagnostic Laboratory. Virus was propagated, and the concentration measured on PK-15 cells as described previously.[10] A standard curve for estimating the concentration of virus in meat samples was prepared by spiking $3.16 \times 10^7$ median tissue culture infective dose (TCID$_{50}$) of virus into a 200 mg ground meat sample. The RNA was isolated from the SVA-spiked meat sample and further diluted to achieve a range of concentrations between $10^1$ and $10^6$ TCID$_{50}$/g

of tissue. The standard curve was plotted as log$_{10}$ TCID$_{50}$/g versus Ct value. For PCR, the standard curve and unknown meat samples were run on the same 96 well plate.

## Results

Ten SVA standard curves were independently generated over the course of the study (Figure 1). The results showed a linear relationship between the Ct value and log virus concentration. The dilution containing approximately 10 TCID$_{50}$ of virus approached a Ct of 40, which is the negative cutoff for the Tetracore PCR assay.

Of the 190 meat samples assayed, only 6 contained a sample of muscle that tested PCR-positive for SVA RNA (Ct value < 40; Table 2). Sample number 1033 and 1076 had Ct values of 36.6 and 37.0, respectively. Based on the standard curve, the estimated virus concentrations for the two positive samples were 1.4 log$_{10}$ and 1.3 log$_{10}$ TCID$_{50}$/g, respectively. The four remaining samples possessed Ct values ranging from 38.4 to 39.2, which were considered borderline positive results. Samples, 1012A, 1022E and 1027G, were from packages that contained multiple cuts of meat. The remaining cuts of meat in each package were assayed and found to be PCR-negative (Ct > 40). The four suspect samples, 1012A, 1022E, 1027G, and 1029E, were subjected to PCR a second time and produced Ct values > 40.

Together, these data show that only 2 of the 190 meat samples possessed detectable quantities of SVA nucleic acid. All PCR-positive samples were negative for the presence of viable virus by virus isolation on PK-15 cells.

## Discussion

Several factors are important for estimating the risk for the introduction of SVA through the exposure of pigs to retail pork products.[11] The first consideration is the prevalence of SVA in the general US pig population. Based on PCR amplification of 2033 oral fluid samples from 25 states, Hause et al[9] provided an estimated prevalence of SVA in the United States at about 1%. In a different study, incorporating the serological analysis of 5957 samples collected in 2016, seroprevalence was estimated at 28.95%.[12] These later data represent pigs that are actively infected as well as pigs that were infected and subsequently cleared the virus. In the present study, 2 of 190 retail meat samples were found to be positive for SVA nucleic acid, supporting Hause's estimate of 1% prevalence.[9]

A second consideration for transmission is the amount of virus present in meat. There are no published studies measuring the concentration of SVA in muscle. However, SVA nucleic acid can be detected in muscle tissue from heart and tongue of infected pigs.[13] In the present study, the highest



**Figure 1:** Generation of the SVA standard curve. Mean and standard deviation for 10 standard curves generated over the course of the study is shown along with the positive-negative cutoff for the Tetracore (Rockville, Maryland) SVA PCR assay, represented by the dashed line. SVA = Senecavirus A; PCR = polymerase chain reaction; Ct = cycle threshold, TCID$_{50}$ = median tissue culture infective dose.
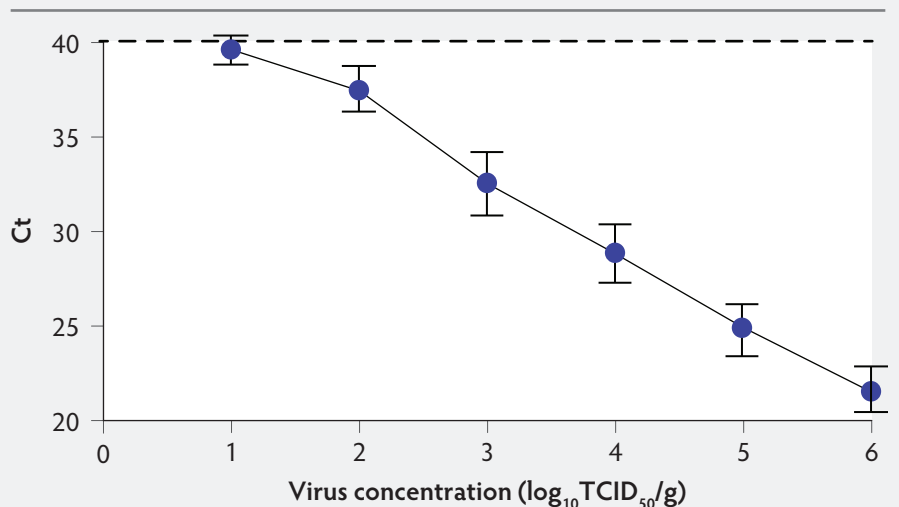
**Table 2:** Packages of meat with PCR-positive samples for SVA RNA*

| Sample No. | Description | Cuts/pkg | Sample ID | Ct | $Log_{10}$ $TCID_{50}$/g |
|---|---|---|---|---|---|
| 1012 | Boneless sirloin chops | 4 | A | 38.4† | 1.0 |
| | | | B | > 40 | < 1.0 |
| | | | C | > 40 | < 1.0 |
| | | | D | > 40 | < 1.0 |
| 1022 | Boneless chops | 7 | A | > 40 | < 1.0 |
| | | | B | > 40 | < 1.0 |
| | | | C | > 40 | < 1.0 |
| | | | D | > 40 | < 1.0 |
| | | | E | 38.8† | < 1.0 |
| | | | F | > 40 | < 1.0 |
| | | | G | > 40 | < 1.0 |
| 1027 | Boneless ribs | 7 | A | > 40 | < 1.0 |
| | | | B | > 40 | < 1.0 |
| | | | C | > 40 | < 1.0 |
| | | | D | > 40 | < 1.0 |
| | | | E | > 40 | < 1.0 |
| | | | F | > 40 | < 1.0 |
| | | | G | 39.2† | < 1.0 |
| 1029 | Boneless butt roast | 1 | A | 38.7† | < 1.0 |
| 1033 | Sparerib | 1 | A | 36.6 | 1.4 |
| 1076 | Loin | 1 | A | 37.0 | 1.3 |

\* Samples with CT values < 40 were considered PCR-positive for SVA RNA.

† Samples were PCR-negative (Ct > 40) when assayed a second time.

PCR = polymerase chain reaction; SVA = Senecavirus A; pkg = package; ID = identification; Ct = cycle threshold; $TCID_{50}$ = median tissue culture infective dose.

concentration of virus observed was estimated to be 1.5 $log_{10}$ of virus/g of muscle, which was found in only 1 of 190 meat samples. The small amount of virus in the PCR-positive meat sample was supported by the negative results for virus isolation on PK-15 cells. Since there are no data on SVA concentration in different muscle meats, a wide variety of meats were tested, including both bone-in (n = 80) and boneless (n = 110) cuts.

A third factor related to the risk of transmission is the minimum infectious dose of SVA required to infect a pig when consuming meat. While there are no data for SVA, data are available for FMDV and SVDV. For example, Fukai et al[14] showed that pigs given $10^6$ virions of FMDV by direct oral administration resulted in three of three pigs becoming infected, whereas only one of three pigs were infected when administered $10^3$ virions. However, Yamada et al[15] failed

to infect six pigs given an oral dose of $10^3$ $TCID_{50}$ of FMDV. For SVDV, the direct instillation of 5.3 $log_{10}$ plaque forming units (pfu) in the mouth of pigs did not result in infection, while increasing the amount of virus to 6.8 $log_{10}$ pfu resulted in three of six pigs becoming infected.[16] If similar to SVDV and FMDV, the highest detected concentration of SVA in the present study (1.5 $log_{10}$/g) would represent a negligible risk for transmission via the consumption of muscle meat by pigs.

In summary, the low prevalence of SVA combined with the low concentration of virus in positive meat samples, indicates a negligible risk for the transmission of SVA through the consumption of muscle meats sold at retail. Based on the study design, these results only apply to the United States. However, these results do also indicate a negligible risk for transmitting SVA from the United States through legal trade in pork.

## Implications

- The low prevalence of SVA in the 190 retail-meat samples analyzed in this study, combined with a low concentration of SVA nucleic acid in the two SVA-positive samples, suggest a low risk for transmitting SVA through retail meat.

## Acknowledgements

## Conflict of interest

None reported.

## Disclaimer

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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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# News from the National Pork Board

## National Swine Disease Council formed to help combat foreign animal disease

In 2013, when pork producers faced an outbreak of porcine epidemic diarrhea virus, the US pork industry put a renewed emphasis on farm biosecurity. Today, the US pork industry has aligned its efforts to reduce the risks from foreign animal disease by creating the National Swine Disease Council (NSDC). The NSDC leadership includes representatives from the National Pork Board, National Pork Producers Council, North American Meat Institute, Swine Health Information Center, American Association of Swine Veterinarians, and US Department of Agriculture, as well as state animal health officials.

"The National Pork Board is well positioned to respond having invested producer dollars over the past 30 years to establish research

priorities and response protocols," said Dave Pyburn, Pork Checkoff senior vice president of science and technology. "In the end, it comes down to producer awareness and education, which is our area of expertise. We have outstanding programs in place and pig farmers are committed to on-farm biosecurity procedures." Additionally, 90% of farms have a premises identification number according to a November 2018 producer survey.

A newly emerging disease can also disrupt US pork exports and commerce, negatively impacting pork producers and their businesses. The combined expertise of the participating organizations will center on rapid response to diseases that threaten the US pork industry. Starting with the formation of the NSDC and identification of member participants,

the producers and their organizations will turn their focus toward providing recommendations in collaboration with state and federal animal health officials, and other industry stakeholders, to respond to emerging swine diseases. Any disease could potentially threaten herd health and negatively affect the US pork industry. This focus specifically includes recommending policies for emerging and foreign animal diseases and collaborating with animal health officials, regulatory agencies, and stakeholders to increase understanding of a disease and quick response, as well as promoting acceptance of recommended actions throughout the US pork industry.

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

## Checkoff Swine Health Committee focuses on African swine fever-prevention strategy

The Pork Checkoff's Swine Health Committee met in January during the National Pork Board's Unified Research Meeting to discuss the industry's swine health concerns, review research proposals, and to develop a plan of action for activities in 2019. The main focus of the committee is to prevent or minimize the impact of health challenges to the domestic pork industry. As would be expected, the committee spent most of its time on African swine fever (ASF) and discussing what it can do to aid in the prevention of the disease in the United States.

The Swine Health Committee's plan of action for ASF includes:

1. Develop a task force to specifically focus on ASF action items such as
   - identifying and funding key areas of research for ASF and other foreign animal diseases,
   - development and delivery of information to target audiences, and
   - promotion of the industry to maintain continuity of business and consumer confidence in pork.

2. Continue aggressive support and promotion of the Secure Pork Supply plan and the accompanying data management platform, AgView.
3. Work with allied associations to ensure collaboration and cooperation among all industry partners.

For more information, contact Patrick Webb at **pwebb@pork.org** or 515-223-3441.

## Nominations open for 2019 America's Pig Farmer of the Year award

Nominations for the 2019 America's Pig Farmer of the Year award are being accepted now through Sunday, March 10 at **www. americaspigfarmer.com**. To receive an

application, a farmer must be nominated or self-nominate. Then, the farmer will receive an email with a link to the application, which will be accepted until Monday, April 1.

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

# New study shows US pork's long-term sustainability progress

A new study from the University of Arkansas has confirmed what many have known for some time, America's pig farmers are producing a product that has become increasingly sustainable over the past five decades. According to the new study, A Retrospective Assessment of US Pork Production: 1960 to 2015, the inputs needed to produce a pound of pork in the United States became more environmentally friendly over time. Specifically, 75.9% less land was needed, 25.1% less water, and 7.0% less energy. This also resulted in a 7.7% smaller carbon footprint.

"The study confirms what we as producers have been doing to make good on our ongoing commitment of doing what's best for people, pigs, and the planet, which is at the heart of the industry's We Care[SM] ethical principles," said Steve Rommereim, National Pork Board president and a pig farmer from Alcester, South Dakota. "It's a great barometer of our environmental stewardship over the years and gives us a solid benchmark for future improvements."

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

# Emerging technology focus at the Pork Checkoff

With disruptive technology and innovation impacting the pork industry both negatively and positively, the National Pork Board created a Director of Emerging Technology position in July 2018. This position is focused on understanding how NPB can represent the interests of pig farmers via proactive engagement in the areas of scientific research and technology innovation. The NPB is currently developing a blockchain pilot in the area of sustainability and the Board of Directors announced a strategic partnership with Thrive AgTech and several major US ag companies last November. The livestock sector has received very little attention and outside capital in the innovation area to date, but the potential to highlight pork industry needs and attract innovation is strong.

For more information, contact Bill Even at `beven@pork.org` or 515-223-2600.

# Launch of Dinner at Home in America report and YouTube success

The first report from the Insight to Action research platform, titled Dinner at Home in America, was released in January. The report provides actionable insight for retailers around the nine newly identified consumer meal occasions. During the next several months, the National Pork Board will work with packers, processors, and retail partners to help them better understand these meal occasions, the needs, behaviors, and influences of that occasion, and how the pork industry can better position pork to meet the dining habits of consumers eating at home.

The National Pork Board spent 2018 in partnership with YouTube's FameBit team. These content creators focused on sharing their love of pork with their followers. Two of the most popular sponsored videos, Barbecue Pork Chops and Whole Pork Loin, were with creator Binging with Babish as part of his Basics with Babish video series. The videos generated more than 2.7 million views. The Binging with Babish YouTube channel has 3.6 million subscribers and his video library has garnered 471.5 million views since 2006. The Barbecue Pork Chops video was selected to be shown at a YouTube-sponsored event on January 25, 2019 during the Sundance Film Festival, which draws leaders from the film industry including studio heads, top creators, and talent managers.

For more information, contact Jarrod Sutton at `jsutton@pork.org` or 515-223-2600.

# Canon hired as Director of Communications

The American Association of Swine Veterinarians (AASV) welcomes Dr Abbey Canon as Director of Communications. Canon accepted the position currently held by Dr Harry Snelson, who will assume the position of Executive Director on June 1 after 13 years as Director of Communications.

Canon joins the AASV from the Center for Food Security and Public Health (CFSPH) at Iowa State University. At CFSPH, a key aspect of her role was establishing and maintaining relationships with stakeholders. She managed a nationally collaborative project, of which the purpose was to foster partnerships with public health, animal health, and youth agricultural organizations to prevent zoonotic influenza and other zoonoses among youth involved in animal agriculture. She also developed new and updated existing training modules for the US Department of Agriculture's Animal and Plant Health Inspection Service National Veterinary Accreditation Program.

In addition to earning her DVM from Iowa State University in 2011, Canon also holds a Master of Public Health and is board certified as a Diplomate of the American College of Veterinary Preventative Medicine. As a postdoctoral research associate at Iowa State University's Swine Medicine Education Center, she trained 4th year swine veterinary students and developed curriculum primarily focused on food safety, public health, and occupational safety. She currently chairs the AASV Human Health and Safety Committee.

Dr Tom Burkgren, AASV Executive Director, noted, "I am thrilled for Dr Canon to join the AASV staff. She brings with her a great background in the areas of communication, education, and public health within the veterinary medical community."

During 2012 to 2014, Canon served as an Epidemic Intelligence Service officer (EISO) with the Centers for Disease Control and Prevention, assigned to the Wisconsin Division of Public Health's Bureau of Communicable Diseases and Emergency Response. As an EISO, she was responsible for responding to urgent or emergent public health threats and communicating critical messages to lay and scientific audiences.

Dr Canon says, "I am so excited to serve AASV in this role. I enjoy education and outreach and am looking forward to strengthening relationships within the AASV, the veterinary profession, and beyond. If we haven't met, please introduce yourself in Orlando!"

Dr Canon started in her new role on February 4, 2019. Please join us in welcoming Abbey to the AASV staff.

# Swine externship opportunities and funding available for students

Veterinary students, are you planning a swine-based externship experience? The AASV Foundation provides grants of $200 to $500 to veterinary students who complete an externship of at least two (2) weeks in a swine practice or a mixed practice with a considerable swine component. Any AASV student member in veterinary school who fulfills the requirements is eligible to apply. More information can be found at **www.aasv.org/students/externgrant.htm**.

Student members of AASV have access to a database of swine-oriented internship and externship opportunities, found at **www.aasv.org/internships/index.php**.

All AASV members who would like their internship and externship opportunities included in this directory are encouraged to contact Jonathan Tubbs, AASV student delegate (**aasvstudentdelegate@gmail.com**), for more information.

# AASV Annual Meeting proceedings online

The proceedings of the 2019 AASV Annual Meeting are available at **www.aasv. org/annmtg/proceedings** for members to download.

The proceedings are available in the following formats:

- The "big book" of all the regular session papers in a single PDF file with a linked table of contents
- Seminar booklets: a PDF file for each seminar

- Individual papers in the Swine Information Library: **www.aasv.org/library/ swineinfo/**

To access the files, make sure your AASV membership has been renewed for 2019. You'll need your AASV website username and password to log in. If they are not handy, contact the AASV office or use the "Reset Password" link in the upper right of the AASV Web site (**www.aasv.org**) to have them emailed to you.

# Alternate Student Delegate selected for AASV Board

The AASV Student Recruitment Committee is pleased to announce the selection of Jamie Madigan (NCSU, 2021) as the incoming Alternate Student Delegate to the AASV Board of Directors. Madigan's passion for swine medicine started during high school while she was working on a grow-finish farm. "I enjoyed walking the barn, and working directly with the pigs, from cleaning feeders to vaccinations," Madigan recalls. A porcine reproductive and respiratory syndrome outbreak piqued her interest in swine health and prompted her to contact Dr Billy Flowers at North Carolina State University (NCSU).

This led to a job at the NCSU swine unit where she learned about treatment options and how proper daily management and nutrition could play a key role in the health of each pig. These experiences solidified her desire to become a swine veterinarian.

She was selected as the Swine Scholar in the Food Animal Scholars program at NCSU. This meant that Madigan had secured a seat at the NCSU College of Veterinary Medicine (CVM) that would allow her to follow her dream to become a swine veterinarian. Prior to entering the NCSU CVM, she took advantage of an opportunity to work with Smithfield Hog Production under Dr Jeremy Pittman. Working with Dr Pittman afforded her the opportunity to routinely visit farms, conduct research projects, and work side-by-side with veterinarians, contract producers, farm managers, and employees - providing a wealth of practical experience.

During her first year at the NCSU CVM, Madigan developed the first food animal speed-networking event at NCSU called Building Bridges. The event allowed a group of food animal veterinarians an opportunity to meet with students to discuss their career, give advice, and simply interact with future veterinarians. She hopes this will become an annual event.

Following Madigan's first year of veterinary school, she had the pleasure of working with Dr Joshua Duff at Goldsboro Milling, Co through the Swine Veterinary Internship Program. While working with him, she gained additional clinical skills and conducted a vaccination protocol comparison trial, which will be presented during the poster session at AASV.

Upon graduation, Madigan hopes to enter practice and continue to work with AASV to help contribute to the continued connection of swine-interested veterinary students with mentors that will help cultivate their passion for this profession.

Madigan assumes her duties as Alternate Student Delegate during the 2019 AASV Annual Meeting in Orlando, Florida. The previous alternate delegate, Jonathan Tubbs (Auburn, 2020), has assumed the delegate position previously held by Jordan Gebhardt (Kansas State University, 2019), who has rotated off the board. Jonathan and Jamie will represent student interests within AASV as non-voting members of the Board of Directors and the Student Recruitment Committee. Please join us in welcoming Jamie to the AASV Board of Directors and thanking Jordan for his service!

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[2]Trials 6-10 - References available upon request.
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# Schmidt family establishes debt-relief scholarship

The AASV Foundation is pleased to announce the establishment of a new scholarship to help relieve the student debt of recent veterinary graduates engaged in swine practice. The $5000 scholarship will be awarded annually to an AASV member who is between 2 and 5 years post-graduation from veterinary school and who carries a significant student debt burden.

The scholarship was initiated with a $110,000 contribution to the foundation by the Conrad Schmidt and Family Endowment. Dr Schmidt, a charter member of AASV, explained, "Together, Judy and I noticed that many new DVM graduates interested in swine medicine begin their professional life with heavy educational debt obligations. As a long-time AASV member and animal industry supporter, it was our desire to help AASV members who have dedicated their professional skills to swine herd health and production. We hope that this endowment will grow over time to assist in reducing the educational debt load of AASV members as they begin their professional journeys."

Applications are being accepted through March 1 for the first scholarship to be awarded during the 50th AASV Annual Meeting in Orlando. The application form is available at **www.aasv.org/foundation/debtrelief.php**. The following criteria will be used to select the scholarship recipient:

- Joined AASV as a student enrolled in an AVMA-recognized college of veterinary medicine
- Attended the AASV Annual Meeting as a student
- Maintained continuous membership in AASV since graduation from veterinary school
- Is at least 2 years and at most 5 years post-graduation from veterinary school
- Has been engaged in private practice, 50% or more devoted to swine, providing on-farm service directly to independent pork producers
- Has a significant student debt burden

For more information, contact the AASV Foundation: **aasv@aasv.org**, 515-465-5255.

# AASV Foundation Fundraising

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programs, see **www.aasv.org/foundation.**

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# Industry Modifies Disease Response Council

In the November and December 2017 issue of the *Journal of Swine Health and Production*, I described the formation of the Swine Disease Response Council.[1] The Council, patterned after the Pseudorabies Control Board active during the pseudorabies virus (PRV) eradication efforts in the 1990s, was charged with providing recommendations regarding responding to emerging diseases.

During the Council's most recent meeting on December 18 in Des Moines, the group's name was changed to the National Swine Disease Council (NSDC) and the charge was expanded to include any diseases significantly impacting the US swine industry including foreign animal diseases (FAD). The mission of the NSDC is to provide recommendations to animal health officials and industry stakeholders to mitigate threats and negative impacts to the US pork industry from diseases of concern. While the recommendations do not carry regulatory authority, they will be developed in coordination with regulators familiar with the industry in an effort to harmonize response activities.

The makeup of the Council remains unchanged and is comprised of key industry leaders addressing distinct areas of swine science expertise. The NSDC leadership includes representatives from the National Pork Board, National Pork Producers Council, North American Meat Institute, Swine Health Information Center, American Association of Swine Veterinarians, and the US Department of Agriculture (USDA), as well as state animal health officials.

The Council's focus will be to provide recommendations, in collaboration with state and federal animal health officials and other industry stakeholders, to respond to swine diseases. The change in the Council's mission recognizes that any disease could potentially threaten herd health and negatively affect the US pork industry and the response to those diseases would benefit from an industry and government collaborative approach. The Council's focus specifically includes:

- Outbreaks of foreign and emerging diseases in the United States,

- Outbreaks of non-regulatory diseases in the United States, and

- Foreign or emerging diseases that are not present in the United States but pose a significant threat to US pork production if introduced.

## Outbreaks of foreign animal and regulatory diseases

In the event of an outbreak of a World Organization of Animal Health-listed FAD or current or future regulatory disease (eg, pseudorabies, swine brucellosis), state and federal animal health officials have regulatory authority to lead the response. The NSDC will play a supportive role developing recommendations prior to or during an outbreak that will help achieve USDA's response goals, which are:

- Detect, control, and contain the disease in pigs as quickly as possible;

- Eradicate the disease using strategies that seek to stabilize animal agriculture, the food supply, the economy, and protect public health; and

- Provide science- and risk-based approaches and systems to facilitate continuity of business for non-infected animals and non-contaminated animal products.

## Outbreaks of non-regulatory emerging diseases

In the event of an outbreak of a non-regulatory emerging disease of concern, the NSDC will use a standardized process to coordinate state-federal-industry cooperative efforts to identify, characterize, prioritize, and respond to the outbreak. The NSDC will facilitate the development of recommended response actions and identify the responsible parties and funding mechanisms necessary to implement the recommended actions needed to better protect the US swine herd.

## Threats to US pork production from foreign or emerging diseases

In the event there is a disease of concern that threatens the US pork industry but is not present in the United States, the NSDC will analyze available information to develop the context and situational awareness to determine appropriate response recommendations. The NSDC will identify the responsible parties and funding mechanisms necessary to implement the recommended actions needed to better protect the US swine herd.

Following the successful eradication of PRV from the US commercial swine herd, the Pseudorabies Control Board was disbanded effectively ending any structured industry-driven collaboration with state and federal animal health officials on disease outbreak response. The NSDC is an effort to revitalize that critical role. The Council will be an integral part of analyzing future disease outbreaks and providing a structured opportunity for stakeholder and government collaboration on the response strategy. While non-binding, the recommendations of the Council should carry considerable weight given the makeup of the Council and the collaborative nature of the interactions.

Harry Snelson, DVM
Director of Communications

## Reference

1. Snelson, H. Swine industry implements group to address emerging diseases. *J Swine Health Prod*. 2017;25(6):333-334.

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## American Association of Swine Veterinarians 50th Annual Meeting

March 9-12, 2019 (Sat-Tue)
Hilton Orlando Buena Vista Palace
Lake Buena Vista, Florida

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

## World Pork Expo

June 5-7, 2019 (Wed-Fri)
Iowa State Fairgrounds
Des Moines, Iowa
Hosted by the National Pork Producers Council

For more information:
Web: www.worldpork.org

## 8th International Symposium of Emerging and Re-Emerging Pig Diseases

June 23-26, 2019 (Sun-Wed)
CasaPiedra Conference Center
Santiago, Chile

For more information:
Email: emerging2019@grupodos.cl
Web: emerging2019.com

## IXth International Conference on Boar Semen Preservation

August 11-14, 2019 (Sun-Wed)
Hunter Valley, NSW, Australia

Abstract deadline: March 1
Earlybird registration deadline: May 10

For more information:
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## Asian Pig Veterinary Society Congress 2019

August 26-28, 2019 (Mon-Wed)
BEXCO, Busan 55, APEC-ro, Haeundae-gu, Busan
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For more information:
Amy Chang (Secretariat of APVS 2019):
802, InnoN, 66, Seongsui-ro, Seongdong-gu, Seoul
Republic of Korea
Tel: +82 2-2190-7331
Email: moon@innon.co.kr
Sue Jo (Secretariat of APVS 2019):
Tel: +82 2-2190-7327
Email: sue@innon.co.kr
Web: www.apvs2019.com

## Pig Welfare Symposium

November 13-15, 2019 (Wed-Fri)
Hosted by the National Pork Board

For more information:
Web: www.pork.org/pws

## 26th International Pig Veterinary Society Congress

June 2-5, 2020 (Tue-Fri)
Florianopolis, Brazil

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

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

# AASV Industry Support Council

*Photo Corner*

An Iowa piglet with heart.

*Photo courtesy of Grant Allison, DVM
from Walcott Veterinary Clinic, Walcott, Iowa*

# AASV Resources online at www.aasv.org