

JOURNAL OF SWINE HEALTH & PRODUCTION

Effects of feeder hole and group size
on feed intake, growth performance,
and lesions

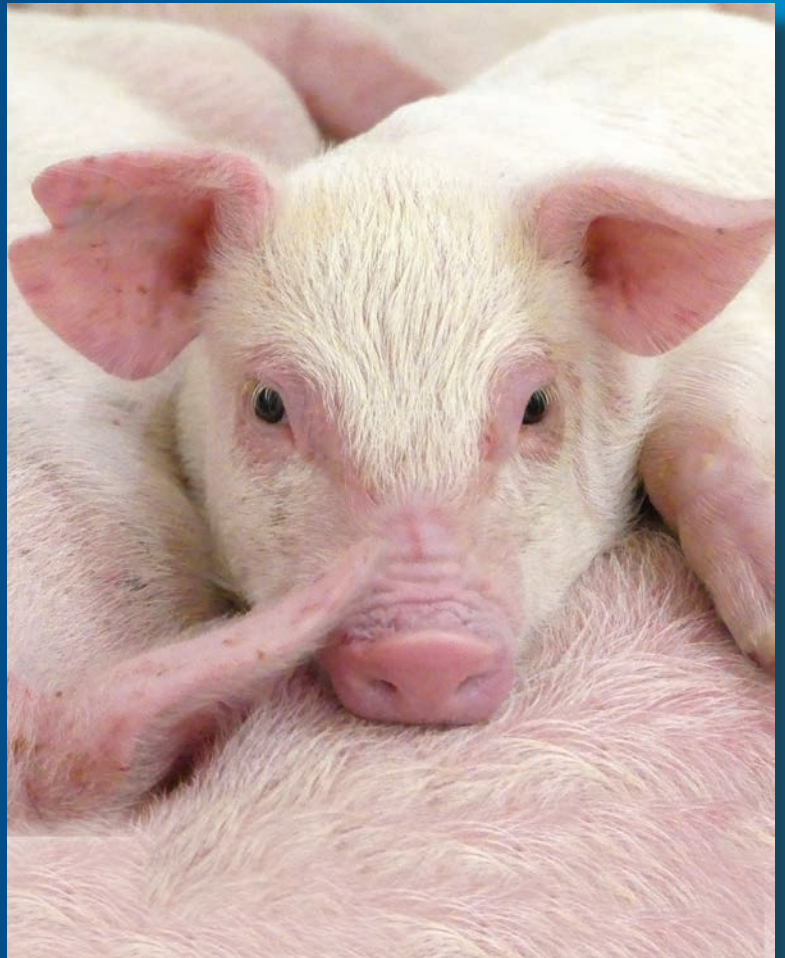
Laskoski F, Faccin JEG, Vier CM, et al

A retrospective analysis of seasonal
growth patterns of nursery and
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Microbiological evaluation of offal
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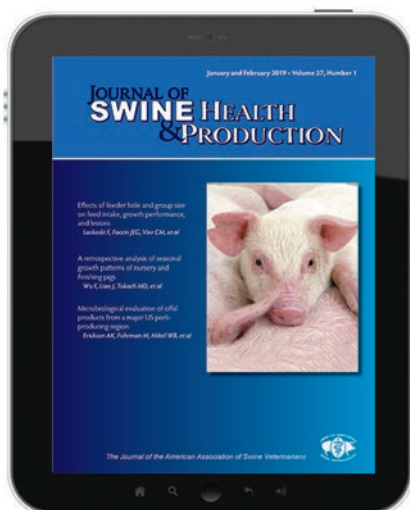
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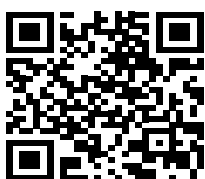
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About the cover...

Ontario nursery pig.
Photo courtesy of Terri O'Sullivan

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“My time spent with the members of AASV has shown me that the unwavering strength of an organization is based in values and beliefs that remain true and constant through the years.”

quoted from the Executive Director's message, page 7



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The AASV: 50 years past and future!

This year, the American Association of Swine Veterinarians (AASV) will celebrate 50 years of progress at our annual meeting. What a tremendous accomplishment! In this issue's message, I want to highlight some features of our organization that I feel are part of our past success and will continue to be important in the future.

What are the things that have made our organization *Built to Last* and are inherent in our success and longevity?

Members. Our membership is a strength of the AASV. The individual strengths and perspectives each of us brings to the collective benefit of all is simply amazing.

Staff. For an organization our size, we are blessed to have a very capable and competent staff. Their dedication is obvious in the AASV activities and operations.

Commitment to mission. The AASV has held true to its core mission throughout the years. The mission has not always been exactly the same, undergoing periodic revisions over time to reflect new focus. I've included our current Mission for your review.



It is the mission of the American Association of Swine Veterinarians to:

- *increase the knowledge of swine veterinarians*
- *protect and promote the health and well-being of pigs*
- *advocate science-based approaches to veterinary, industry, and public health issues*
- *promote the development and availability of resources that enhance the effectiveness of professional activities*
- *create opportunities that inspire personal and professional growth and interaction*
- *mentor students, encouraging life-long careers as swine veterinarians*

I think we are doing a fabulous job advancing our mission, what do you think?

Annual meeting. The annual meeting is the cornerstone of our organization. It provides an excellent opportunity for swine veterinarians to gain education on current topics and a venue for professional interaction. This networking event is important to veterinarians, students, academics, and industry professionals. I hope to see you in Orlando this spring for our 50th Anniversary Annual Meeting!

Organizational structure. Our organizational bylaws govern our activities. Our board of directors, elected by the membership, meets twice per year to review the organization's activities and take actions. Our committees meet once a year in person at the annual meeting and have the opportunity to meet more often by conference call. Committees have been active in advancing position statements and initiatives for the AASV Board to consider.

Financial stability. Our organization has never been financially stronger. Our balance sheet is reviewed twice a year by the Board of Directors. Our budget is developed by a three-member committee and approved each year by the Board of Directors. Our financial records are reviewed by an independent accounting firm once a year. We believe that we are well positioned financially to take advantage of new opportunities and withstand challenges we may encounter. The AASV Foundation

continues to grow and provide opportunities in support of our mission. This year provides an additional opportunity for the Foundation to grow; I hope you will consider the multiple ways to lend your financial support.

Innovation. Our organization has been willing to change when needed. One example is changing our name from American Association of Swine Practitioners to American Association of Swine Veterinarians to make our organization more identifiable to others. We have seen the need for the formation of new organizations, like the Professional Animal Auditor Certification Organization, serving as a founding organizational member. We have been willing to start new member services, like the Summer Conference, and discontinuing them when the need and value to membership subsides. We give thought to the formation of new committees and have sunset them when they are no longer needed.

Research. Robust research is part of our membership and organizational culture. Many of our members are actively engaged in research as their principal focus. Other members serve on boards or committees that decide what research is important for swine and determine financial support for research proposals. Our AASV Foundation funds several research projects each year and provides support for students engaged in research.

Environment. Our culture has fostered a very inclusive environment for the sharing of new ideas and commitment to solving new problems in swine health and welfare. When there is dissent, it is shared in a very respectful and productive way.

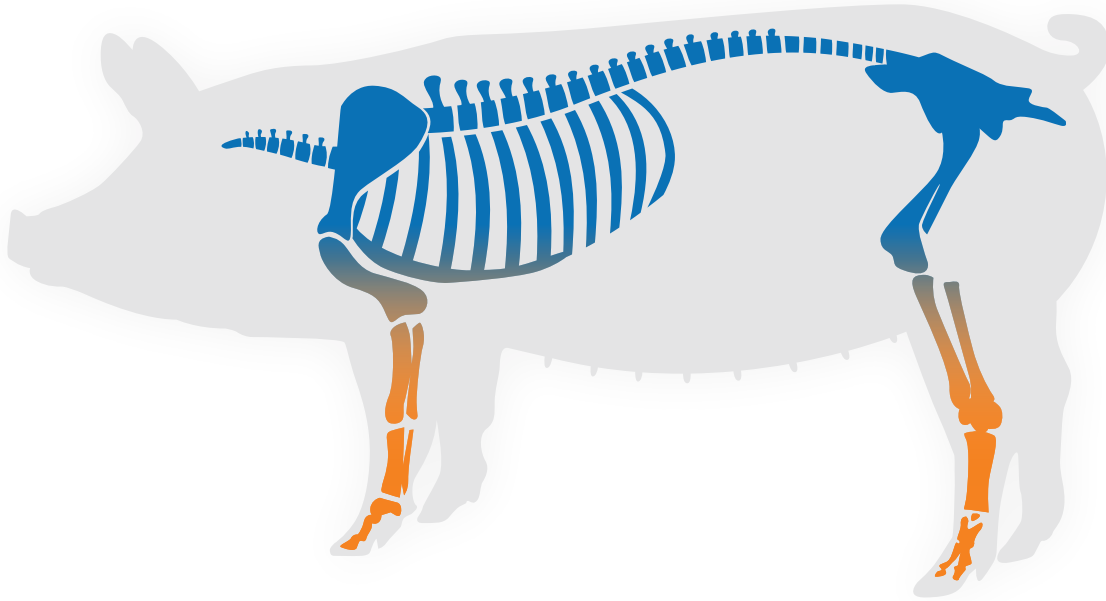
Leadership. We have been blessed to have Dr Burkgren's leadership as executive director for almost half of our organization's existence. I am very pleased in the selection of Dr Harry Snelson as his successor. It has been an honor for me to have served as president this year. Thank you very much for this opportunity.

I hope you are as proud of our heritage and excited as I am for the next 50 years!

C. Scanlon Daniels, DVM
AASV President



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Upcycled thoughts

One of the most difficult tasks I've had in my job over the years has been to write my message for *Journal of Swine Health and Production* every other month. My struggle is to come up with something new and fresh so that I don't bore the few members who happen to read it. You would think that as my tenure with AASV draws to a close in 2019 that the words would flow with mighty advice and grand visions for the association. Alas, words fail me. So, I went back to the May and June 2000 issue of JSHAP and pulled up my very first message. I find it just as applicable today as I did back then. What follows is an updated version of that message.

I am at a loss to find words to adequately describe my experiences over the last 25 years with the AASP/AASV. I was new on the job in 1994 when Steve Henry asked me why I would take a job with the association. I replied, "I like working without a net!" I responded in that manner because that is how association work had been described to me: association employees walk a tightrope, working at the whim of officers, boards, and committees. Now as I look back, I realize that reply does not do justice to the privilege of serving the

members of the AASV. I have had a net the entire time. This net is made up of some of the most dedicated and inspired people I have seen in my career.

Ken Blanchard, management expert, describes a style of management in which you are "catching people doing things right." This also describes my experiences while working for the AASV. This is an organization that has had people "doing things right" since the formation of the AASP in 1969. This is an organization filled with people willing to look beyond the philosophy of "what's in it for me?" It is amazing how many times in 25 years I have heard the words "how can I help?" The AASV is blessed with members willing to provide countless hours as volunteers so that all swine practitioners might benefit.

The veterinarians who volunteer for the AASV fill many roles. Some roles are more visible than others. Yet all roles directly affect the success of the association. The AASV would not be the strong organization of today without the time and effort put forth in past years by active and engaged members. These members saw their efforts as an investment in the AASV and not as a cost to themselves.

Having said all the above is the easy part. Now comes the part that has turned my hair gray: How does the AASV continue its success? How does the AASV continue to educate and inform swine veterinarians? How does the AASV continue to effectively advocate for the veterinary profession and the swine industry? The questions could continue for a long time. Fortunately, the answers can be found within the same premise that has brought the AASV this far: encouraging and facilitating the philosophy of members serving members.

The following are a few of my observations of the drivers for the future success of the AASV:

- Ensuring that the right people are in the right place at the right time.
- Providing resources to do what needs to be done.

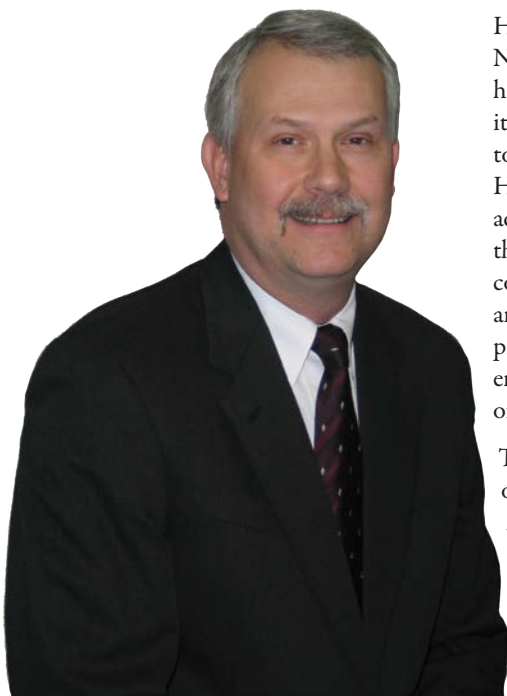
"Just as vital, however, is your involvement as a member who contributes ongoing input to the AASV on how well the association is meeting your needs as a swine veterinarian."

- Allowing younger members to assume leadership roles.
- Keeping long-time members engaged and accessible.
- Maintaining a "lean and mean" organizational structure, staff, and office.
- Segmenting the membership to ensure that all needs are adequately met.
- Surpassing the expectations of all who interact with the AASV.
- Providing the best education, information, networking, and advocacy for swine practitioners.

The best advice I can give to any member is to get involved. Your involvement may be in the form of service as an officer, director, committee member, or representative to another organization. Just as vital, however, is your involvement as a member who contributes ongoing input to the AASV on how well the association is meeting your needs as a swine veterinarian. Let the AASV know how we are doing and what we can be doing better.

Some might consider me lazy for recycling this message, and that opinion may well be justified. However, I like to believe that the core values of the AASV have not changed. My time spent with the members of AASV has shown me that the unwavering strength of an organization is based in values and beliefs that remain true and constant through the years. The key to future success is grounded in those same values and beliefs.

Tom Burkgren, DVM
Executive Director





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Comparison of the pharmacokinetics and efficacy of two different iron supplementation products in suckling piglets

Chris W. Olsen, DVM, MS; Lars Lykke Thomsen, MD, PhD, DMSc

Regarding the research article by Morales et al¹ in the July and August 2018 issue of the *Journal of Swine Health and Production*, we challenge the relevance of the pharmacokinetic (PK) measures used in the study and their basis for drawing any conclusion to the relative bioavailability of injectable iron products for swine.

Based on the observation that gleptoferron had a higher serum iron area under the curve (AUC) in comparison to iron dextran, the authors have concluded that gleptoferron is more bioavailable. However, as reported in human literature,

*Standard approaches are not appropriate when assessing pharmacokinetics of iron supplements due to the ubiquity of endogenous iron, its compartmentalized sites of action, and the complexity of the iron metabolism. The primary site of action of iron is the erythrocyte, and, in contrast to conventional drugs, no drug-receptor interaction takes place. Notably, the process of erythropoiesis, i.e., formation of new erythrocytes, takes 3–4 weeks (in humans). Accordingly, serum iron concentration and area under the curve (AUC) are clinically irrelevant for assessing iron utilization.*²

To understand why this is the case and consequently why the conclusions by Morales et al are invalid, we must understand the basic principles of iron absorption and transport as described by Crichton³ and Geisser and Burckhardt.² Iron-carbohydrate complexes injected intramuscularly are initially taken up from the injection site by macrophages of the reticuloendothelial system where the iron molecule is gradually separated from the carbohydrate carrier. Within the macrophage, iron is either bound in the iron-carbohydrate complex or by the iron-storage protein ferritin for transient storage; or it is exported to the blood where it is bound to transferrin, the protein responsible for transportation of iron molecules through the serum to their site of utilization or storage. The iron binding capacity of transferrin is

very limited, on the order of approximately 0.1% of the total body iron content, and if overwhelmed, can lead to labile iron in the serum. Free or labile iron is highly toxic hence the importance of iron transport and storage being tightly controlled.⁴ Upon complete absorption and incorporation into the body's iron storage, iron functions as a reserve that is gradually transported to the bone marrow for use in hemoglobin synthesis in a process that takes several days to weeks. It is the availability of storage iron that is critical to the rise in hemoglobin over several weeks observed in this and essentially all other studies on injectable iron products, not the short-term peak in serum iron observed within the first day by Morales et al.

We contend that bioavailability measured as serum iron concentration is not a relevant measure based on the early history of parenteral iron therapy dating back to the 1930s.⁵ Researchers at Harvard Medical School injected adult humans with iron salts, i.e. free iron not bound by a complex. The authors concluded that

Iron in doses of 16 to 32 mgm (mg) a day, given parenterally, is very close to the maximum amount of iron tolerated by man. It is attended by disagreeable symptoms, sometimes severe and possibly dangerous.

This illustrates that even low doses of free iron is toxic and, in a sense, too bioavailable. The ideal parenteral iron preparation ensures slow gradual release of the iron so as not to overwhelm the natural transport and storage mechanisms.

The basic flaw made by Morales et al is failure to consider the pharmacodynamics of the products they studied in determining which PK variables to measure and how to interpret them. Specifically, their conclusion that a larger AUC of serum iron for gleptoferron equates to a higher bioavailability is unfounded based on the previously stated principles of iron storage and transport. The higher serum iron concentrations for gleptoferron than for iron dextran should

be considered from a safety stand point as it could suggest a higher risk of saturating the transferrin binding capacity leading to free iron toxicity. Further, Morales et al did not report whether they measured free- or total-serum iron, which is important when considering the toxic effects of free iron.

When considering the clinically relevant hematologic parameters such as red blood cell count and hemoglobin concentration, the levels reported in the iron dextran group were at or above those of the gleptoferron product. We contend that the values at the end of the study are of primary interest and emphasize that no differences were found for any hematologic parameter between the two products.

Thus, a reasonable interpretation of the study results would be that the two products show some differences in their PK profile, but that they result in similar efficacy. If any more substantial conclusion were to be made, it would be that iron dextran is more available to ferritin, the body's natural iron stores, and that the higher serum iron concentrations associated with gleptoferron could be associated with increased risk of free or labile iron reactions, which should be further investigated.

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Pharmacosmos Inc, Watchung, New Jersey.

Author response: Comparison of the pharmacokinetics and efficacy of two different iron supplementation products in suckling piglets

Daniel Sperling, DVM, PhD; Hamadi Karembé, DVM, MSc; Joaquin Morales, DVM, PhD; Albert Manso, DVM; Tomás Martín-Jiménez, DVM, PhD, DACVCP, DipECVPT

We thank the authors of the Letter to the Editor (Olsen and Thomsen) for their interest in our article published recently in this journal.¹ We would like to address the questions they have raised.

Relevance of selected method

The bioavailability of the intravenous route is 100% per definition and the intestinal absorption of iron and its retention is tightly regulated via homeostasis. Therefore, pharmacokinetics or bioavailability assessment is less relevant for oral and intravenous iron, the main routes of application used in humans.² Note that the human medicine literature² quoted in Olsen and Thomsen's letter to the Editor focuses on oral and intravenous application, not intramuscular (IM) application.

Serum or plasma iron and area under the curve are relevant for assessing the iron utilization, or pharmacodynamics, following IM application. This is highlighted in the guidance documents issued by the regulatory authorities in the United States³ (Food and Drug Administration) and Europe⁴ (European Medicines Agency).

Increase from the baseline is commonly used for assessment of endogenous compounds as it gives the real effect of the hematinic product as the primary outcomes (eg, hemoglobin (Hb) and hematocrit) are linked to the initial values. In the case of the Morales et al study,¹ all hematological parameters, including Hb values, were not significantly different at study day 0 ($P = .15$), therefore the increases can be compared. Only red blood cell counts were significantly different ($P = .01$), but remained in the normal range during the entire study.

Piglets are born with low iron storage and without early and efficient iron supplementation they become anemic within the first

week of life.⁵ It is therefore important that plasma iron is rapidly incorporated into the immature red cells⁵ and that iron stores are replenished (bone marrow, liver, and spleen). Rapid absorption and utilization of IM iron are both important for the prevention of the iron deficiency in piglets. It is also known that the iron remaining at the injected site 72 hours after injection will remain trapped and not available for Hb synthesis.^{6,7} This non-absorbed iron will deposit in the connective tissue stroma and associated macrophages, resulting in unacceptable muscle or skin staining.⁷ Slow and incomplete absorption of iron might be one of the frequently discussed reasons of the sub-anemic status of piglets at weaning and consequently the need for a second iron injection.⁸

The importance of absorption, or pharmacokinetics, on the efficacy, or pharmacodynamics, of different IM iron formulations is well documented in early literature dealing with the discovery and development of proper iron complex formulations for IM application.^{6,7,9,10}

Studies of the metabolic fate of iron dextran in animals and humans have shown that the material follows a distinct pathway after intravenous or IM injection.¹¹ After IM injection, the iron complex is first cleared into the reticulo-endothelial system (RES). Within phagocytes, iron is released from the iron-carbohydrate compound and either incorporated by ferritin into intracellular iron stores or released from the cell to be taken up by the extracellular iron-binding protein, transferrin. Transferrin delivers iron to transferrin receptors on the surface of erythroid precursors for Hb synthesis and maturation of the red blood cell.

The well-established safety of gleptoferron

High molecular weight iron polysaccharide complexes are very stable and well tolerated allowing, for the first time, delivery of large intravenous doses without saturation of transferrin and toxicity.¹² In addition, the IM route is less prone to iron overload than intravenous iron, as the injected iron complex is taken up and processed by the RES and transferred gradually to the erythroid precursor and storage organs.

Gleptoferron-based products have good safety records. Intramuscular application of the standard iron dose (200 mg/piglet) showed optimal transferrin saturation, which remains within the normal physiological range.^{13,14}

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Effects of pigs per feeder hole and group size on feed intake onset, growth performance, and ear and tail lesions in nursery pigs with consistent space allowance

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Summary

Objective: To determine the effects of varying the number of pigs per feeder hole and group size on feed intake onset, growth performance, and lesions in nursery pigs.

Materials and methods: A total of 630 pigs were randomly assigned at weaning (mean [SD] age of 20.5 [0.9] d and weight of 5.59 [0.9] kg) to one of four treatments: 3.75, 5.00, 6.25, or 7.50 pigs per feeder hole, which was achieved by altering group size with 15, 20, 25, or 30 pigs per pen, respectively. Pigs were fed a meal diet containing 1% iron oxide dye for three days post-weaning. Rectal swabs

were evaluated to assess the onset of feed intake. Pigs were weighed weekly and presence of ear and tail lesions were recorded.

Results: Decreasing the number of pigs per feeder hole resulted in a decrease in onset of feed intake ($P < .001$). Average daily gain tended to increase linearly as the number of pigs per feeder hole decreased ($P = .06$). No statistically significant responses were observed for average daily feed intake and feed efficiency ($P > .12$). The lowest occurrence of tail lesions ($P < .05$) was observed in the treatment with 3.75 pigs per feeder hole. The highest incidence ($P < .05$) of ear

lesions occurred in the treatment containing 7.50 pigs per feeder hole.

Implications: Decreasing the number of pigs per feeder hole in the nursery period may result in faster onset of feed intake, improved growth performance, and reduced ear and tail lesions.

Keywords: swine, nursery, growth, ear lesions, tail lesions

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Resumen – Efectos de cerdos por abertura de comedero y tamaño de grupo en el inicio del consumo de alimento, desempeño de crecimiento, y lesiones de cola y oreja en cerdos en el destete con acceso de espacio consistente

Objetivo: Determinar los efectos al variar el número de cerdos por abertura de comedero y tamaño de grupo en el inicio del consumo de alimento, desempeño del crecimiento, y lesiones en cerdos en el destete.

Materiales y métodos: Se asignaron al azar un total de 630 cerdos al destete (media [DS] con edad de 20.5 [0.9] d y peso de 5.59 [0.9] kg) a uno de cuatro tratamientos: 3.75, 5.00, 6.25, ó 7.50 cerdos por abertura de comedero, lo que se logró al alterar el tamaño del grupo con 15, 20, 25, ó 30 cerdos por corral, respectivamente. Los cerdos fueron alimentados con un alimento con un contenido de 1% de colorante de óxido de hierro por tres días post destete. Se evaluaron hisopos rectales para determinar el inicio del

consumo de alimento. Los cerdos se pesaron semanalmente y se registró la presencia de lesiones de cola y oreja.

Resultados: La reducción del número de cerdos por abertura de comedero resultó en un descenso en el inicio del consumo de alimento ($P < .001$). La ganancia diaria promedio tendió a aumentar linealmente al disminuir el número de cerdos por abertura de comedero ($P = .06$). No se observaron respuestas estadísticamente significativas en el consumo de alimento diario promedio y la eficiencia alimenticia ($P > .12$). La ocurrencia más baja de lesiones de cola ($P < .05$) se observó en el tratamiento con 3.75 cerdos por abertura de comedero. La incidencia más alta ($P < .05$) de lesiones de oreja ocurrió en el tratamiento con 7.50 cerdos por abertura de comedero.

Implicaciones: La reducción del número de cerdos por abertura de comedero en el periodo de destete puede resultar en un inicio más rápido del consumo de alimento, un mejor desempeño de crecimiento, y una reducción de las lesiones de cola y oreja.

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Résumé – Effets du nombre de porcs par espace d'alimentation et de la taille du groupe sur le début de la prise d'aliment, les performances de croissance, et les lésions aux oreilles et à la queue chez des porcs en pouponnière avec une allocation d'espace constante

Objectif: Déterminer les effets d'une variation du nombre de porcs par espace d'alimentation et de la taille du groupe sur le début de la prise d'aliment, les performances de croissance, et les lésions chez des porcs en pouponnière.

Matériels et méthodes: Un total de 630 porcs a été réparti de manière aléatoire au moment du sevrage (moyenne [ET]; à l'âge de 20.5 [0.9] j et au poids de 5.59 [0.9] kg) à l'un de quatre traitements : 3.75, 5.00, 6.25, ou 7.5 porcs par espace d'alimentation, qui a été obtenu en modifiant la taille du groupe avec 15, 20, 25, ou 30 porcs par enclos, respectivement. Les porcs ont reçu un aliment contenant 1% d'un colorant d'oxyde de fer pendant trois jours post-sevrage. Des écouvillons rectaux ont été évalués pour déterminer le début de la prise d'aliment. Les porcs étaient pesés à chaque semaine et la présence de lésions aux oreilles et à la queue était notée.

Résultats: Une diminution du nombre de porcs par espace d'alimentation a résulté en une diminution du moment de la prise d'aliment ($P < .001$). Le gain quotidien moyen avait tendance à augmenter de manière linéaire à mesure que le nombre de porcs par espace d'alimentation diminuait ($P = .06$). Aucune différence statistiquement significative ne fut observée pour la quantité quotidienne moyenne d'aliment ingéré et l'efficacité alimentaire ($P > .12$). La fréquence la plus faible de lésions à la queue ($P < .05$) a été observée dans le groupe avec 3.75 porcs par espace d'alimentation. La fréquence de lésions aux oreilles la plus élevée ($P < .05$) s'est produite dans le groupe avec 7.50 porcs par espace d'alimentation.

Implications: Une diminution du nombre de porcs par espace d'alimentation pendant la période en pouponnière pourrait résulter en un début plus rapide de la prise d'aliment, une amélioration des performances de croissance, et une diminution des lésions aux oreilles et à la queue.

Low feed intake in the post-weaning period and consequent low growth can impair performance and negatively affect metabolism and health status in pigs.^{1,2} Although the effect of the number of pigs per feeder hole has been widely studied in production settings, few studies have evaluated its impact on growth performance, the onset of feed intake after weaning, and the incidence of ear and tail lesions. Wolter et al³ investigated the effects of feeder space and space allowance in wean-to-finish barns and observed a decrease in feed intake in pens with 18 pigs per feeder hole compared to those with 9 pigs per feeder hole up to 98 days post-weaning. However, no significant differences were observed in the overall growth rate and final body weight.

Lindemann et al⁴ suggested that when feed is provided ad libitum, pigs do not need to eat in groups or to have access to the feeder simultaneously, which would lessen the impact of the availability of feeder space. This phenomenon, however, has not been documented when ad libitum feed is provided during the nursery phase under high stocking density conditions. Preferable space allowances per pig, within the body weight ranges of 5 to 6 kg and 25 to 30 kg, are from 0.25 m² to 0.30 m², on slatted floors.⁵ With higher stocking densities, there is a competition for space and the likelihood of animals having a limited access to the feeder is increased. DeDecker et al⁶ evaluated the effect of stocking density on pig performance in a wean-to-finish production system and suggested that the feeder space may have a negative influence on the growth rate of animals under a higher stocking density. This supports our idea that higher stocking density without an increase in the number of feeder holes can impair the performance.

The competition for feed can not only reduce growth performance but also trigger aggressive interactions between the animals.⁷ Botermans et al⁷ observed that the most common interactions between pigs experiencing a feed competition during the growth phase included biting, pushing, and knocking of heads. The occurrence of tail biting indicates that some or all pigs within a pen are experiencing reduced welfare.⁸ However, very few studies have been published to evaluate the effects of number of pigs per feeder hole in pigs housed under commercial conditions and higher stocking density on ear and tail biting during the nursery phase.

Therefore, this study aimed to determine the effects of number of pigs per feeder hole and number of pigs per pen on the onset of feed intake post-weaning, growth performance, and the incidence of ear and tail lesions in nursery pigs under commercial conditions and with consistent space allowance.

Materials and methods

Institutional ethics committee approval

The Institutional Animal Care and Use Committee of the Federal University of Rio Grande do Sul approved the protocols used in this experiment according to the process PROPESQ-UFRGS 30556.

Animals, housing, and experimental design

The trial was conducted at a commercial research nursery facility in Videira, Santa Catarina, Brazil from May to July of 2016. A double curtain-sided nursery room with 28 identical pens, each with a total area of 6.84 m², was used for the experiment. All pens had solid concrete flooring along the entire length of the feeder, and slatted plastic flooring in the remaining area. The room temperature was maintained at 28°C to 30°C in the first and second week of the trial, and 25°C to 26°C thereafter. The temperature was monitored using three data loggers and two thermometers located at the center and extreme sides of the room.

A total of 630 intact males and gilts (PIC 337 × Camborough, Pig Improvement Company, Hendersonville, Tennessee), with initial mean (SD) body weight (BW) of 5.59 (0.9) kg and weaning age of 20.5 (0.9) days, were used in a 42-day study. The piglets' needle teeth were ground after birth and one third of their tails were docked at 3 days of age. At weaning, pigs were individually weighed, ear-tagged, and assigned to pens to achieve balanced gender and weight across the pens. Pens of pigs were randomly allotted to one of four treatments in a completely randomized manner, with 7 replicate pens per treatment. Treatments consisted of 3.75, 5.00, 6.25, and 7.50 pigs per feeder hole, which were achieved by increasing group size with 15, 20, 25, and 30 pigs per pen, respectively. Adjustable pen gates were used to maintain a floor space allowance of 0.23 m² per pig across treatments. Therefore, the resulted pen dimensions were 4.28 × 1.6 m², 3.56 × 1.6 m², 2.85 × 1.6 m², and 2.15 × 1.6 m²

for treatment groups with 3.75, 5.00, 6.25, and 7.50 pigs per feeder hole, respectively. Pen sizes were adjusted in the event of pig death or removal for poor health.

Each pen contained a semi-automatic feeder with a polypropylene reservoir and a stainless-steel tray with four feeding holes, each 16 cm wide by 14 cm deep (Veromix 40 C Premium Nursery Feeder, Magnani, Seara, Brazil), which provided a total space of 64 cm in length. Feeders were located at the front of the pens. Pigs had ad libitum access to a corn- and soybean-meal-based diet in a three-phase feeding program formulated according to the National Research Council.⁹ All diets were manufactured at the on-farm feed mill and were fed in meal form. The feed budget was 1 kg of Phase 1 diet fed per pig (3.6 Mcal/kg of metabolizable energy [ME], 21.9% crude protein [CP], and 1.46% standardized ileal digestible [SID] Lysine), 4 kg of Phase 2 diet fed per pig (3.6 Mcal/kg of ME, 21.4% CP, and 1.42% SID Lysine), followed by a Phase 3 diet (3.5 Mcal/kg of ME, 20.1% CP, and 1.30% SID Lysine) with approximately 17 kg/pig fed until the end of the trial. In addition, the drinkers were placed in the back third of the pen, on the side opposite to the feeder. Pens with 15 and 20 pigs had 2 nipple drinkers, and pens with 25 and 30 pigs had 3 drinkers to achieve a relatively similar number of pigs per nipple drinker in each pen (7.5, 10, 8.3, and 10, respectively).

Pigs presenting any health issues were treated according to the production company's standard animal husbandry procedures.

Onset of feed intake

Four pens per treatment were randomly selected to receive the Phase 1 diet with the inclusion of 1% iron oxide as a red fecal marker. The onset of feed intake was evaluated for the first 66 hours post-weaning in each individual pig by rectal swab over seven time-intervals: 18, 26, 34, 42, 50, 58, and 66 hours. A red colored swab indicated the onset of feed consumption. This technique was followed as previously described by Bruninx et al¹⁰ and Sulabo et al¹¹, who evaluated the percentage of pigs eating creep feed using fecal markers.

Ear and tail lesions

The presence of ear and tail lesions, which may be indicative of ear and tail biting, were recorded. Deeper lesions were considered, differentiating them from scratches. Observations

were conducted by one veterinarian. Pigs with severe ear and tail lesions were removed from the pen but were included in the statistical analysis.

Growth performance

Individual pig weights on days 0 (weaning day), and 42 were used to determine the coefficient of variation (CV) within each pen. The total weight of pigs and feed disappearance of each pen were measured to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F:G). Growth performance data of the overall period were split into 3 periods of 14 days: period 1 (0 to 14 d); period 2 (15 to 28 d); and period 3 (29 to 42 d).

Pigs were removed from pens only upon death or if identified to be in a non-ambulatory condition and not responding to medical treatment. In such cases, adjustments were made at the pen level using adjustable gates to account for removed or deceased pigs and maintain the same floor space allowance of 0.23 m² per pig until the end of the trial.

Statistical analysis

Data were analyzed as completely randomized design using the GLIMMIX procedure of SAS software (Version 9.4, Institute Inc, Cary, North Carolina), considering pen as the experimental unit. Polynomial contrasts were implemented to evaluate the linear and quadratic effects of the dose-response (varying the number of pigs per feeder hole and pigs per pen) on average time of onset of feed intake, ADG, ADFI, BW, F:G, CV, mortality, and removal rate. For mortality and removal rate, a binomial distribution was fit to the data. The IML procedure of SAS was used to adjust linear and quadratic coefficients after accounting for unequally spaced treatments. The non-parametric NPAR1WAY procedure of SAS was used to analyze the percentages of ear and tail lesions, and groups were compared using the Kruskal-Wallis test. Results were considered significant at a $P \leq .05$ and a trend at $P \leq .10$.

Results

Throughout the experimental period, 20 pigs were removed, and 15 deaths were recorded; however, there was no effect ($P > .05$) of number of pigs per feeder hole on removals and mortality rate (Table 1).

Average time to onset of feed intake decreased as the number of pigs per feeder hole

and the number of pigs per pen decreased (Linear, $P < .001$; Figure 1).

For period 1 (day 0 to 14), a decrease in the number of pigs per feeder hole by decreasing the number of pigs per pen resulted in a linear increase in ADFI ($P = .02$; Table 2). Variations in ADG and F:G and were not statistically affected by treatments ($P > .05$). For period 2 (day 15 to 28), ADG increased linearly ($P = .01$) as the number of pigs per feeder hole decreased to 3.75, or 15 pigs per pen. This was likely driven by a linear improvement in F:G as the number of pigs per feeder hole and pigs per pen decreased ($P = .02$). There was a tendency for a quadratic improvement in ADFI ($P = .068$) as the number of pigs per feeder hole decreased from 7.50 to 6.25 pigs per feeder hole (30 to 25 pigs per pen), with no improvement thereafter. During period 3 (day 29 to 42), none of the growth performance criteria were affected by treatments ($P > .05$). Overall (day 0 to 42), there was a tendency ($P = .06$) for a linear improvement in ADG as the number of pigs per feeder hole decreased from 7.50 (30 pigs per pen) to 3.75 (15 pigs per pen). There were no differences in ADFI, F:G, BW, and CV as the number of pigs per feeder hole and pigs per pen decreased ($P > .05$).

Percentages of ear and tail lesions are shown in Table 3. Pens with 3.75 pigs per feeder hole (15 pigs per pen) had no ear or tail lesions. Pigs in pens with 7.50 pigs per feeder hole (30 pigs per pen) had significantly more ear lesions than pens with fewer pigs per feeder hole ($P < .05$). Pigs in pens with 3.75 pigs per feeder hole (15 pigs per pen) had significantly fewer tail lesions when compared to the other 3 treatments ($P < .05$).

Discussion

In this study, the influence of variation in the number of pigs per feeder hole, by varying the number of pigs per pen while maintaining the same space allowance, on growth performance, the onset of feed intake, and incidence of ear and tail lesions was investigated.

A change in environment (eg, diet type, drinkers, cohort, etc) creates challenges to weaned pigs, especially relative to voluntary feed intake.¹² Pens with 3.75 pigs per feeder hole, or 15 pigs per pen, had the lowest average time to the onset of feed intake after weaning and highest ADFI in the first 14 days post-weaning compared to the other treatments. These results agree with those from Weber et al¹³ who observed a tendency

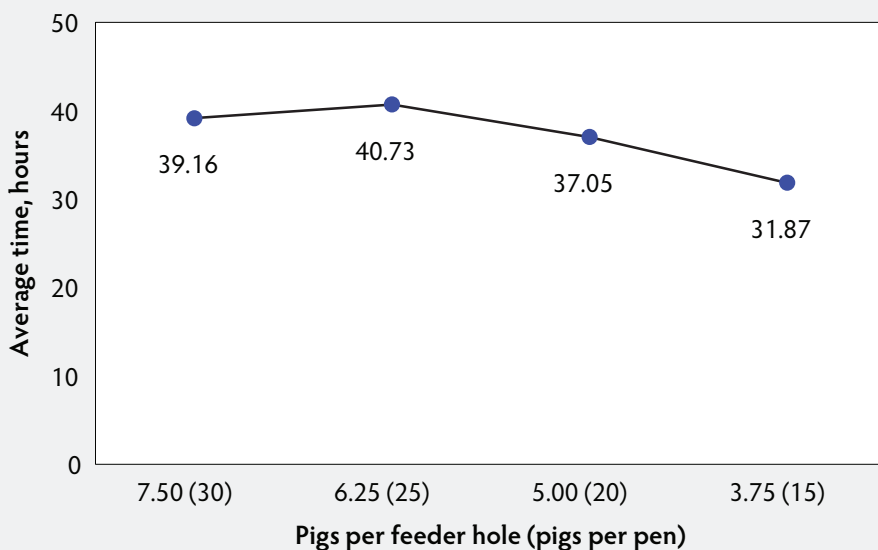
Table 1: Effects of pigs per feeder hole on the removal rate and mortality of pigs with consistent space allowance during the nursery period*

	Pigs per feeder hole (Pigs per pen)				SEM	Probability, P_{\dagger}	
	7.50 (30)	6.25 (25)	5.00 (20)	3.75 (15)		Linear	Quadratic
Removals, %	4.3	4.6	1.4	0.9	0.341	.14	.87
Mortality, %	1.0	2.9	3.6	2.9	0.453	.30	.19

* A total of 630 pigs (PIC 337 × Camborough; initial BW 5.59 ± 0.9 kg) were used with 0.23 m^2 of floor space allowance per pig and 7 replicate pens per treatment. The nursery period is classified as weaning to 42 days.

† Polynomial contrasts were implemented to evaluate the linear and quadratic effects.
SEM = standard error of the mean.

Figure 1: Average time to the onset of feed intake according to the number of pigs per feeder hole and pigs per pen during the nursery period. Polynomial contrasts were implemented to evaluate the linear and quadratic effects of a 42-d study on nursery pigs comparing different proportions of pigs per feeder hole. Standard error of the mean = 0.953; Linear, $P < .001$; Quadratic, $P = .08$.



for improved feed intake as the number of pigs per feeder hole was reduced. A positive relationship between feed intake and villous height or villus to crypt ratio has been previously reported.¹⁴⁻¹⁶ Therefore, enhancing feed intake in the weaned pig is critical to overcome post-weaning challenges and prevent villous atrophy, reduce post-weaning diarrhea, and stimulate growth performance.²

In the present study, the difference between the two extreme treatments (3.75 and 7.5 pigs per feeder hole) was 3.75 pigs. In another study,¹³ in which the difference between the two extreme treatments (8.9 and 12.4 pigs per feeder hole) was similar to that used in the present study, no differences were observed in growth rate until the end of the 8th week after weaning, at a floor space of 0.26 m^2 per

pig. It is possible that the small variation in the number of pigs per feeder hole between treatments explains the linear increase in ADG observed only during the second period as well as the linear trend of overall increasing ADG, as the number of pigs per feeder hole was decreased by reducing the number of pigs per pen. When a greater difference in the number of pigs per feeder hole between treatments was evaluated (9 and 18 pigs per feeder hole) in a wean-to-finish system, no differences were observed in growth performance in the first six weeks post-weaning.¹⁷ However, in the grower phase (7th and 8th weeks), the treatment of 9 pigs per feeder hole had higher ADG and BW compared with 18 pigs per feeder hole. Unlike the present work, these authors¹⁷ used a floor space of 0.30 m^2 per pig, which may explain that once the space

allowance becomes a limiting factor for the animals (> 6th week), a greater feeder space becomes more determinant for improving growth performance.

Tail biting is a multi-factorial problem and factors that can induce frustration or psychological discomfort may trigger or intensify tail biting occurrence.¹⁸ Among these factors, limited space allowance,¹⁹ limited feed availability,²⁰ increased number of pigs per feeder hole,²¹ and reduced feed space per pig²² are associated with aggressive interactions such as ear and tail biting. Delays in accessing feed are associated with stress and increased restlessness among pigs.²³ Competition for food (such as access to the feeder) will increase the potential for some pigs to become frustrated, because they are not free to eat at desired times or to consume the desired amount of feed, hence leading to tail biting.^{21,24} It has been shown that five or more pigs per feeder hole are 2.7 times more likely to be subjected to or to perform ear and tail biting than pigs kept at a lower number of animals per feeder hole during the growing and finishing phases.¹⁹ In the present study, the treatment providing 3.75 pigs per feeder hole, or 15 pigs per pen, had no ear or tail lesions and was the only treatment with less than five pigs per feeder hole. Although more aggressive interactions among the pigs can be expected in large groups, the effect of group size on tail biting remains unclear.^{18,25} No effect of group size (22 vs 44 or 18 vs 108 pigs per pen) has been observed in docked pigs,^{18,26} but Kallio et al²⁷ reported that groups with more than 9 long-tailed pigs were at higher risk of tail biting in finishing units. Although aggression and competition to access feed were not assessed in the present study, the dispute for feed access was shown to be more influenced by the availability of feeder space per pig than the total number of animals in the pen.²⁸ We can speculate that

Table 2: Effects of pigs per feeder hole on growth performance of pigs housed with consistent space allowance during the nursery period*

	Pigs per feeder hole (Pigs per pen)				SEM	Probability, P [†]	
	7.50 (30)	6.25 (25)	5.00 (20)	3.75 (15)		Linear	Quadratic
Period 1 (0 to 14 days)							
ADG, g	176	181	170	185	0.008	.57	.41
ADFI, g	225	239	244	254	0.007	.02	.71
F:G	1.28	1.32	1.39	1.34	0.042	.34	.13
Period 2 (15 to 28 days)							
ADG, g	349	368	361	381	0.007	.01	.99
ADFI, g	509	538	525	525	0.007	.37	.07
F:G	1.47	1.47	1.48	1.38	0.025	.02	.07
Period 3 (29 to 42 days)							
ADG, g	509	504	539	545	0.023	.18	.81
ADFI, g	816	818	834	843	0.020	.28	.91
F:G	1.61	1.59	1.51	1.55	0.038	.20	.21
Overall period (0 to 42 days)							
ADG, g	343	351	357	370	0.010	.06	.91
ADFI, g	516	534	533	541	0.009	.11	.49
F:G	1.46	1.48	1.47	1.42	0.023	.22	.25
Body weight, kg							
d 0	5.58	5.59	5.60	5.58	0.010	.82	.23
d 14	8.07	8.10	7.99	8.27	0.010	.16	.21
d 28	13.18	13.29	13.03	13.42	0.206	.51	.40
d 42	20.73	21.22	21.12	21.55	0.314	.12	.84
Individual body weight CV, %							
Initial (weaning)	16.6	16.6	16.9	16.9	0.164	.39	.29
Final (42 d)	19.0	17.0	16.4	17.0	0.671	.20	.41

* A total of 630 pigs (PIC 337 × Camborough; initial BW 5.59 ± 0.9 kg) were used with 0.23 m² of floor space allowance per pig and 7 replicate pens per treatment. The nursery period is classified as weaning to 42 days.

† Polynomial contrasts were implemented to evaluate the linear and quadratic effects.

SEM = standard error of the mean; ADG = average daily gain; ADFI = average daily feed intake; F:G = feed for 1 kg of gain; CV = coefficient of variation.

Table 3: Ear and tail lesions according to the number of pigs per feeder hole during the whole nursery period*

	Pigs per feeder hole (Pigs per pen)			
	7.50 (30)	6.25 (25)	5.00 (20)	3.75 (15)
Ear lesions, %	5.7 ^b	0 ^a	0.7 ^a	0 ^a
Tail lesions, %	11.9 ^b	9.7 ^b	6.4 ^b	0 ^a

* A total of 630 pigs (PIC 337 × Camborough; initial BW 5.59 ± 0.9 kg) were used with 0.23 m² of floor space allowance per pig and 7 replicate pens per treatment. The nursery period is classified as weaning to 42 days.

^{a,b} Percentages followed by different letters within the row differ statistically ($P < .05$). Groups were compared by the Kruskal-Wallis test.

the higher occurrence of ear and tail lesions in the treatment with 7.50 pigs per feeder hole was mainly associated with the increase in pigs per feeder hole since the space allowance was the same (0.23 m² per pig) for all pigs of the present study; however, a combined effect of the larger group size (30 pigs per pen) in this treatment cannot be discarded.

In large group sizes, social organization of the pigs may be altered, although the exact group size this occurs is unknown.²⁹ Given that group size and number of pigs per feeder hole changed simultaneously across the treatments, it is not possible to separate the relative effects from each of these factors on the responses observed in this study. However, results from previous research provide some indication that may explain the dynamic of the effects on performance caused by these two factors. Spoolder et al²⁸ reported no effect on growth performance (from 36 to 85 kg BW) with group sizes of 20, 40, and 80 pigs per pen. Likewise, Wolter et al³⁰ observed similar growth rates for groups of 25, 50, or 100 pigs in a wean-to-finish system. Evaluating the association between feeder space and group size, Turner et al³¹ reported that a reduction in feeder space from 4.25 to 3.25 cm per pig during the growing and finishing periods significantly decreased feed intake regardless of group size (20 vs 80 pigs per pen). The range of group sizes of the present study (15 to 30 pigs per pen) was relatively narrower than that used in the aforementioned studies in which the growth performance was not affected by the group size. It is important to note that, in the current study, although the number of pigs per pen changed along with the number of pigs per feeder hole, the stocking density was kept the same across all treatments using movable gates.

Reducing the number of pigs per feeder hole through a decrease in group size can be a valid strategy to improve growth performance and animal welfare when space allowance is restricted. Importantly, number of pigs per feeder hole and group size should be considered when planning the placement of pigs in nurseries. Further research evaluating the effects of number of nursery pigs per feeder hole under restricted space allowance while maintaining constant group size is warranted.

Implications

Under the conditions of the present study, decreasing the number of pigs per feeder hole through a reduction in group size while maintaining a consistent space allowance:

- Reduced the incidence of ear and tail lesions.
- Tended to increase growth rate during the overall period.
- Reduced the time to onset of feed intake and increased feed consumption in the initial phase of the nursery period.

Acknowledgments

Conflict of interest

None reported.

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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

$$^{\circ}\text{F} = (^{\circ}\text{C} \times 9/5) + 32$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9$$

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
	99	45
Grower	110	50
	132	60
	198	90
	220	100
	231	105
Finisher	242	110
	253	115
	300	135
	661	300
	794	360
Sow	800	363
Boar		

$$1 \text{ tonne} = 1000 \text{ kg}$$

$$1 \text{ ppm} = 0.0001\% = 1 \text{ mg/kg} = 1 \text{ g/tonne}$$

$$1 \text{ ppm} = 1 \text{ mg/L}$$

A retrospective analysis of seasonal growth patterns of nursery and finishing pigs in commercial production

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Summary

Objective: Determine seasonal patterns of nursery and finisher growth performance in 3 commercial US production systems located in the midwest.

Materials and methods: Five years of production records, including 5039 nursery and 5354 finisher production batches, were collected from 3 production systems. Explanatory variables include system, site, pig-flow type, feeder type, batch size, week of placement, average days-on-feed, fill length, number of sow farm sources, dietary energy, mortality, and initial body weight. Week of placement served as the unit for seasonal patterns. Nursery and finisher performance

(average daily gain [ADG], average daily feed intake [ADFI], and gain to feed ratio [G:F]) were analyzed in separate datasets using multi-level linear mixed models. A guided stepwise selection approach was used to select fixed variables and their interactions. Seasonality curves were generated using rolling averages of least squares means with a 5-week window and 1-week step-size.

Results: For nursery, the seasonality effect was significant ($P < .001$) for ADG, ADFI, but not for G:F. Nursery ADG and ADFI decreased as week of placement progressed from the 1st to 20th week of a year but increased thereafter. All finisher growth responses were affected by week of placement

($P < .001$) but the pattern and magnitude of seasonal variability differed among systems (system \times week interactions, $P < .02$).

Implications: Seasonal variability of nursery and finisher performance can be quantified using production records in a multi-level linear mixed model. Seasonality effects on finisher performance were system dependent, while nursery seasonality shared more similarity among investigated systems.

Keywords: swine, seasonality, growth performance, nursery, finisher

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Resumen – Análisis retrospectivo de modelos de crecimiento estacional de cerdos de destete y finalización en producción comercial

Objetivo: Determinar los modelos estacionales en el desempeño del crecimiento en el destete y la finalización en 3 sistemas de producción comercial del medio oeste de los EUA.

Materiales y métodos: Se recolectaron cinco años de registros de producción, incluyendo 5039 grupos de producción de destete y 5354 grupos de producción de finalización, de 3 sistemas de producción. Las variables descriptivas incluyeron el sistema, tipo de flujo de cerdos, tipo de comedero, tamaño del grupo, semana de llegada, promedio de días en alimento, duración de llenado, número de granjas origen, energía dietética,

mortalidad, y peso corporal inicial. La semana de colocación sirvió como la unidad para los modelos estacionales. Se analizó el desempeño de destete y finalización (ganancia diaria promedio [ADG por sus siglas en inglés], consumo de alimento diario promedio [ADFI por sus siglas en inglés], y ganancia a alimento [G:F por sus siglas en inglés]) en grupos separados de datos utilizando un modelo multi-nivel lineal mixto. Se utilizó un método de selección paso a paso guiado para seleccionar variables fijas y sus interacciones. Se generaron curvas estacionales utilizando promedios móviles con bloques de cinco 5 semanas y un paso de 1 semana.

Resultados: En destete, el efecto de temporada fue significativo ($P < .001$) para ADG, ADFI pero no para G:F. La ADG y ADFI en destete disminuyó al avanzar la semana de llegada de la 1ra a la 20ava semana del año pero se aumentó a partir de entonces. Todas las respuestas del crecimiento en finalización fueron afectadas por la semana de llegada ($P < .001$) pero el modelo y la magnitud de la variabilidad de temporada difirieron entre los sistemas, (sistema \times interacción de la semana, $P < .02$).

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Wu F, Liao J, Tokach MD, et al. A retrospective analysis of seasonal growth patterns of nursery and finishing pigs in commercial production. *J Swine Health Prod.* 2019;27(1):19-33.

Implicaciones: La variabilidad de estación del desempeño del destete y finalización pueden cuantificarse utilizando registros de producción con un modelo multi-nivel lineal mixto. Los efectos de estación en el desempeño de finalización fueron dependientes del sistema, mientras que los efectos estacionales en destete compartieron una mayor semejanza entre los sistemas investigados.

Résumé – Analyse rétrospective des patrons de croissance saisonnière de porcs en pouponnière et en finition dans une production commerciale

Objectif: Déterminer les patrons saisonniers des performances de croissance de porcs en pouponnière et en finition dans trois systèmes de production commerciale américains situés dans le midwest.

Matériels et méthodes: Les relevés de production d'une période de 5 ans, incluant 5039 et 5354 lots de production de porcs en

pouponnière et en finition, respectivement, ont été prises de trois systèmes de production. Les variables descriptives incluaient le système, le site, le type de flux des porcs, le type de mangeoire, la taille du lot, la semaine de placement, la moyenne de jours nourris, le temps de peuplement, le nombre de ferme d'origine des truies, l'énergie alimentaire, le taux de mortalité, et le poids corporel initial. La semaine de placement a servi d'unité pour les patrons saisonniers. Les performances en pouponnière et en finition (gain moyen quotidien [ADG], consommation alimentaire moyenne quotidienne [ADFI], et ratio gain sur nourriture [G:N]) ont été analysées dans bases de données séparées en utilisant des modèles linéaires mixtes à niveaux multiples. Une approche de sélection progressive guidée a été utilisée pour sélectionner les variables fixes et leurs interactions. Les courbes saisonnières ont été générées en utilisant les moyennes de roulement des moyennes des moindres carrés avec une fenêtre de 5 semaines et une progression de 1 semaine.

Résultats: Pour la pouponnière, l'effet saisonnier était significatif ($P < .001$) pour le ADG et la ADFI, mais pas pour le G:N. En pouponnière, le ADG et la ADFI ont diminué à mesure que les semaines de placement progressaient de la semaine 1 à la semaine 20 d'une année mais ont augmenté par la suite. En finition, toutes les réponses de croissance étaient affectées par la semaine de placement ($P < .001$) mais le patron et la magnitude de variation saisonnière différaient parmi les systèmes (système \times interactions semaine, $P < .02$).

Implications: La variabilité saisonnière des performances en pouponnière et en croissance peut être quantifiée en utilisant les données de production dans un modèle linéaire mixte à niveaux multiples. Les effets saisonniers sur les performances en finition étaient dépendants du système, alors que les effets saisonniers en pouponnière partageaient plus de similarité parmi les systèmes étudiés.

It is widely documented that pig production has seasonal variations.¹⁻³ Pigs have a limited ability to thermoregulate, thus extreme temperatures result in increased reproductive difficulties, reduced growth performance, and elevated mortality.¹ Seasonal heat stress loss estimates indicate a nearly \$300 million annual cost to the US swine industry.⁴

An accurate estimate of seasonal variability in feed consumption and growth rate is essential for commercial producers to estimate feed usage and marketing projections. Coarse estimations of the seasonality curve are sometimes generated based on raw means of weekly production performance. However, the precision of this method may be questioned as it does not account for factors confounded with seasonality. For instance, some nutritional programs feed pigs with increased dietary energy during the summer to counteract the decreased feed intake. Additionally, pigs grow slower and, therefore, producers likely extend their feeding period and change their marketing strategy in the summer compared with other times of the year. These confounding factors along with other production variables, such as different pig flows, feeder types, ventilation designs, and stocking densities, are also known to cause variations in growth and, therefore, need to be accounted for in a seasonality analysis. In a retrospective study conducted in 1995 by Bahnson and Dial,³ seasonal patterns of finisher average daily gain (ADG) and average daily feed intake (ADFI)

in commercial swine production were determined using multiple linear regression models. However, the inference scope of this study is limited to a single production system and such seasonal patterns require validation and an update using current data from modern production systems.

The objective of this study was to develop a systematic modeling approach to estimate the seasonality effects (expressed as the week of placement in a year) on growth performance of nursery and finishing pigs using retrospective commercial production records.

Material and methods

Data collection

Five years of production records from January 2013 to December 2017 were collected from three swine production systems located in the midwestern United States. A total of 5039 nursery and 5354 finisher production batches representing nearly 28 million market pigs were included in the raw dataset. The dataset structure consists of three levels: system, site, and batch. The batch was defined as a cohort of pigs per airspace within a site. In most cases the airspace was defined at the barn level. Some sites consisted of multiple barns, of which production records were reported as separate batches; however, the size of sites (eg, number of barns per site or rooms per batch) was not available for analysis. There were 25, 49, and 126 nursery

sites; 513, 142, and 126 finisher sites; and 398, 52, and 130 wean-to-finish sites in systems A, B, and C, respectively. Explanatory variables collected at the site level were types of pig flow and feeder design. Nursery flow types included conventional nursery (nursery), nursery phase of wean-to-finish flow (WF-nursery), and wean-to-finish facilities that only housed nursery flows (converted-nursery). Finisher flow types included conventional finishing (finishing) and finishing phase of wean-to-finish flow (WF-finishing). At the batch level, data collected included starting and ending inventory, start date, close date, average days on feed (DOF), length of fill period, number of sow farm sources (sowfarm), average dietary net energy (NE), mortality, initial body weight (BW), final BW, ADG, ADFI, and gain to feed ratio (G:F). The final BW of WF-nursery batches and the initial BW of WF-finishing batches were determined based on pigs that were loaded onto trucks, weighed, and transferred from the wean-to-finish barn to another finisher; it is assumed that the batch of pigs that stayed in the wean-to-finish barn had similar average BW as those that were transferred out. Start date and close date referred to the first and last day, respectively, that pigs of the batch were in the facility. Average DOF was calculated as the sum of pig days (defined as one live pig being fed for one day) divided by the total number of pigs started. Average dietary NE was calculated based on major ingredient usage per batch and estimated energy density of ingredients.

Data processing

The raw dataset was divided into two subsets for separate analysis of nursery and finisher performance. Because dietary NE data was only available since 2015 in system A, the finisher dataset analysis was limited to 3 years (2015 to 2017) of observations to avoid confounded effects between system and year. However, given that the nutritional programs of the three systems did not alter energy con-

tent of nursery diets over seasons, NE was not considered in the nursery models so that the nursery dataset could include 5 years of data and provide an increased number of replications for seasonality analysis.

Initial diagnosis was performed using scatter plots for each explanatory and outcome variable to identify outliers. Screening criteria and the number of observations removed are presented in Table 1. For the nursery dataset,

observations with suspected errors in BW estimation (ie, ADG < 0), recorded feed usage (ie, G:F > 1000 g/kg), or date recording (ie, fill length > DOF) as well as inaccurate pig counts (ie, mortality < 0) were removed from the dataset. Additionally, observations were removed if DOF < 21 d or final BW > 50 kg because they did not represent the standard pig flow among the systems. For the finisher dataset, observations with suspected

Table 1: Screening criteria for exclusion of nursery and finisher batches from three swine production systems located in the midwestern United States from January 2013 to December 2017

Item	Production system		
	A	B	C
Nursery dataset			
Production batches in the raw dataset, No.	2632	1125	1282
Observation removal, No.			
Inaccurate pig counts*	1	1	9
Average DOF < 21 d	14	2	0
Final BW > 50 kg	26	0	2
Suspected BW estimation errors (ie, biologically abnormal ADG)	7	2	0
Suspected feed accounting errors (ie, G:F > 1000 g/kg)	11	1	0
Suspected date recording errors (ie, fill length > DOF)	1	2	0
Production batches in the final dataset, No.	2572	1117	1271
Value removal, No.			
Feed delivery recording errors†	45	0	4
Removal rate, %	4.0	0.7	1.2
Finisher dataset			
Production batches in the raw dataset, No.	2862	1076	1416
Observation removal, No.			
Unusual pig flow‡	2	0	1
Initial BW < 10 kg	9	1	1
Initial BW > 70 kg	30	1	0
Final BW < 100 kg	16	6	0
Final BW > 150 kg	1	0	0
Suspected feed accounting errors§	14	1	2
Production batches in the final dataset, No.	2790	1067	1412
Value removal, No.			
Feed delivery recording errors†	2	1	0
Suspected dietary energy recording errors¶	23	0	0
Removal rate, %	3.4	0.9	0.3

* Including batches with abnormal inventory and mortality < 0.

† Feed allocation was inaccurately recorded between consecutive batches resulting in abnormal variability in G:F. Only ADFI and G:F values were removed.

‡ Half of the total inventory was filled 90 days after filling of the first half.

§ Including batches with ADFI > 4 kg, ADFI < 1.5 kg, or G:F > 1000 g/kg.

¶ Only net energy values were removed.

DOF = days on feed; BW = body weight; ADG = average daily gain; G:F = gain to feed ratio; ADFI = average daily feed intake.

errors in recorded feed usage (ie, ADFI > 4 kg, ADFI < 1.5 kg, or G:F > 1000 g/kg) were removed. Finisher observations with initial BW < 10 kg or > 70 kg, or final BW < 100 kg or > 150 kg, were considered non-normal production flows and were removed from the dataset. Feed delivery recording errors were identified when feed allocation was inaccurately recorded between consecutive batches resulting in abnormal G:F variability (eg, G:F < 300 g/kg in a batch and G:F > 1000 g/kg in the subsequent batch due to carry over or misallocation of feed among batches or when there was an extreme high and extreme low value among batches within a site). The ADFI and G:F values of these observations were deleted, but ADG values were unchanged.

For each observation, week of placement (week; calendar year beginning January 1) was designated according to the start date and served as the unit for seasonality effect. Pig inventory counts were categorized to form batch size classes to avoid multicollinearity with fill length because batches with greater inventory often required a longer fill period. Sizes of nursery batches include < 3000, 3000 to 6000, and > 6000, and sizes of finisher batches include < 1500, 1500 to 3500, and > 3500. These inventory categories were selected to represent common commercial facility capacities. However, information regarding space allowance, stocking density, or pen or barn dimension was not available from every production system for analysis. In addition, feeder designs were categorized into 3 types: dry, tube, and wet-dry. Facilities equipped with mixed feeder types were assigned a missing value due to the limited number of observations ($n = 137$) with mixed types of feeders.

Statistical analysis

Nursery and finisher datasets were analyzed separately. Average daily gain, ADFI, and G:F were evaluated as response variables. System, flow, size, year, feeder type, and week were treated as categorical variables, while fill length, DOF, mortality, sowfarm, and dietary NE were treated as continuous variables. Quadratic terms of DOF and mortality were evaluated for potential non-linear effects on pig growth responses. Dietary NE was only available for finisher models. In the nursery dataset, converted-nursery was exclusive to system A, resulting in confounded effects between system and flow. Thus, the system and flow variables were merged in the nursery dataset to form a 7-category variable termed system-flow.

For each response variable, first-order ordinary least squares regression models, involving

predictor variables of system (or system-flow in the nursery dataset), year, week, size, fill length, DOF, initial BW, mortality, NE (only for finisher dataset), and feeder type, were constructed for regression diagnostics following procedures described by Chen et al.⁵ Observation leverage was estimated and evaluated in a leverage versus residual squared plot to identify influential observations. Suspected observations were assessed for biological accuracy and recorded in the screening list if removed from the dataset (Table 1). Multicollinearity among predictor variables was tested using variance inflation factor (VIF); variables with VIF values greater than 6 were further diagnosed using two-way scatter plots. There was evidence showing multicollinearity between finisher initial BW and DOF due to a strong, negative linear correlation ($r = -0.83$). Because the alteration of DOF was often considered a part of the seasonality change in finishing pig production (eg, pigs raised during the summer had a longer feeding period than in the winter), initial BW was included in the finisher models instead. However, DOF of nursery batches did not vary significantly over seasons and thus was used in the nursery models. Studentized residuals versus fitted values and studentized residuals versus each categorical descriptive variable plot were examined for heteroscedasticity. Heteroscedasticity was found among systems as observations from system A had consistently greater residual variance compared with systems B and C across all response variables; therefore, a dummy variable (“variance group”; variance group = 1 if system = A, variance group = 0 if system = B or C) was created and accounted for in the analysis.

Multi-level linear mixed models for each response variable were constructed with batch serving as the observational unit, site as a random effect, and system (system-flow in nursery dataset) as a fixed effect. A random residual term of batch within variance group was included in all models to account for heterogeneous variance among systems. A guided stepwise selection approach was employed to select variables and their interaction terms. Specifically, a saturated first-order model was first fit involving all candidate fixed variables. This model was then reduced in a stepwise manner based on variable significance level ($P > .10$) and improvement in Bayesian information criterion (BIC). Possible two-way interactions among remaining fixed variables were introduced to form a saturated two-way model. The final

model was achieved by stepwise removal of interaction terms based on their significance level ($P > .10$) and improvement in model BIC. Bayesian information criterion was used as an indicator of model suitability.⁶ Restricted maximum likelihood method was used in the model selection to evaluate the significance of fixed effect terms. The Kenward-Roger’s procedure was used to estimate degrees of freedom and adjust estimated SE for bias correction. Also, at each model selection step, studentized residuals were evaluated. All analyses were performed using Stata Statistical Software (Release 15; StataCorp LLC, College Station, Texas).

Least squares means for week of placement were generated using the margins command with “asbalanced” and “emptycells(reweight)” options.⁷ To generate a smooth seasonality curve for each growth response, rolling averages of the least squares means were calculated using a centered 5-week window with step-size of 1 week. Rolling averages for weeks 1, 2, 51, and 52 were generated by recursive extension of the week series (eg, rolling average of week 1 represents the mean of weeks 51, 52, 1, 2, and 3). Finally, seasonal patterns were standardized using growth responses in week 1 as a benchmark and that of other weeks were expressed as changes in response relative to week 1.

Results

Descriptive statistics

Explanatory variable frequencies and histograms are presented in Table 2 and Figures 1, 2, and 3. The majority (> 80%) of the nursery batches were filled within 20 days with system A having a longer average fill length than systems B and C. In contrast, the majority of finisher batches were filled within two days. In both nursery and finisher datasets, more than 65% of the production batches sourced pigs from a single sow farm, while about 30% of the batches obtained pigs from 2 to 6 sow farm sources. The number of observations per week of placement varied throughout the year and averaged 95 and 101 batches per week in nursery and finisher datasets, respectively. Descriptive statistics for initial and final BW, DOF, mortality, and growth responses along with US industry benchmarks⁸ are shown in Table 3. The mean values of initial BW were 5.5 and 27.0 kg, final BW were 26.6 and 125.3 kg, DOF were 55.3 and 112.4 days, and mortalities were 4.1% and 4.0% in nursery and finisher datasets, respectively. The mean values of ADG were 370 and 871 g, ADFI

Table 2: Frequency of nursery and finisher batches from three swine production systems located in the midwestern United States from January 2013 to December 2017 for each explanatory variable

Item	Production system		
	A	B	C
Nursery dataset			
Year			
2013	574	212	201
2014	401	211	235
2015	552	226	246
2016	562	222	279
2017	483	246	310
Type of pig flow			
Converted-nursery*	601	0	0
Nursery	816	802	619
WF-nursery†	1155	315	652
Batch size			
< 3000 pigs	1198	583	436
3000 to 6000 pigs	396	237	288
> 6000 pigs	978	297	547
Feeder type			
Dry	543	981	786
Tube	718	12	81
Wet-dry	965	27	295
Missing‡	346	97	109
Finisher dataset			
Year			
2015	908	343	442
2016	986	345	463
2017	896	379	507
Type of pig flow			
Finishing	2084	877	955
WF-finishing§	706	190	457
Batch size			
< 1500 pigs	45	115	143
1500 to 3500 pigs	1231	540	959
> 3500 pigs	1514	412	310
Feeder type			
Dry	95	598	664
Tube	634	289	283
Wet-dry	1787	85	378
Missing‡	274	95	87

* Wean-to-finish facilities that were used for traditional nursery pig flow.

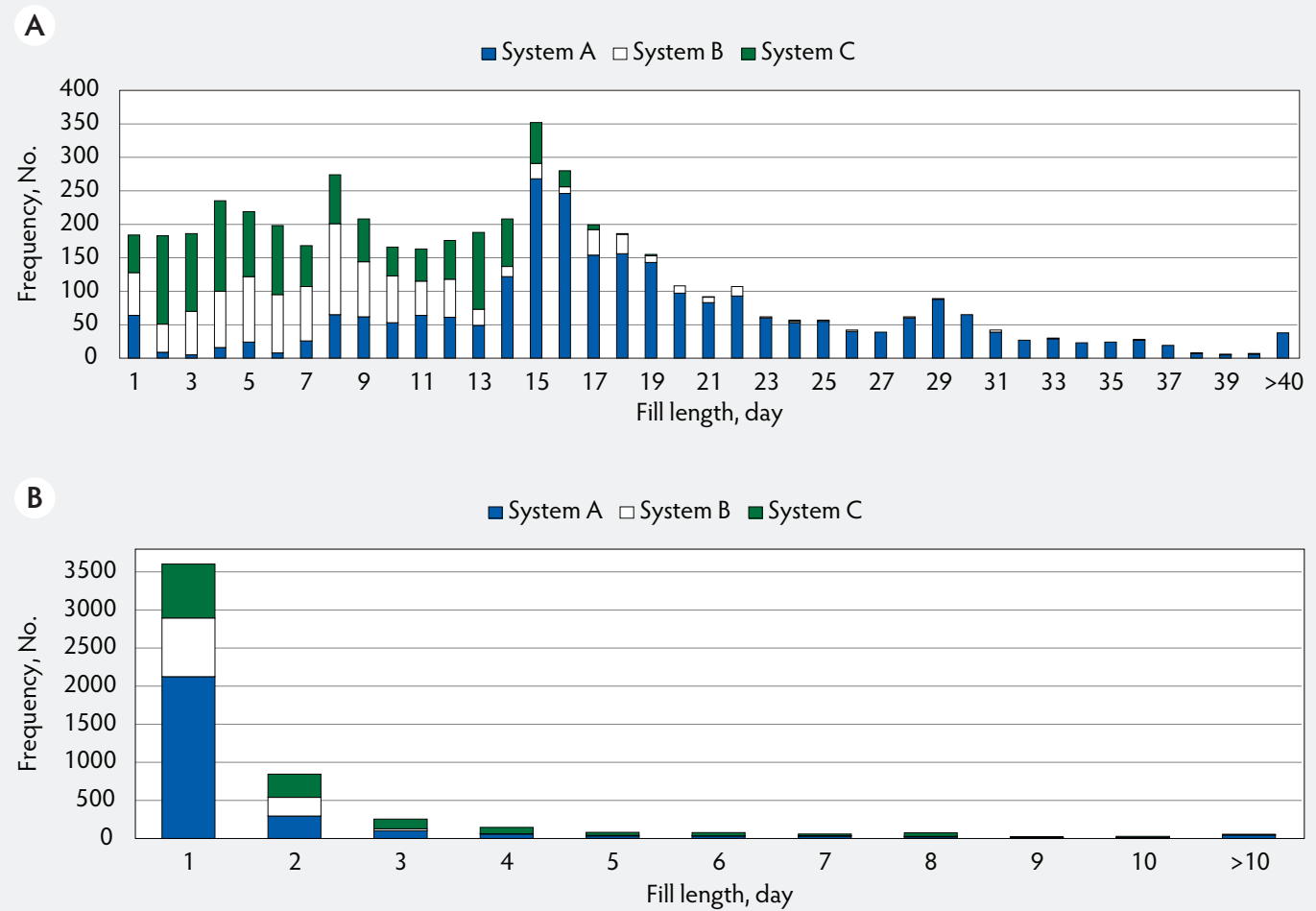
† Nursery phase of wean-to-finish flow.

‡ Including missing information and facilities with mixed feeder types.

§ Finishing phase of wean-to-finish flow.

WF = wean-to-finish.

Figure 1: Frequency distribution of fill length for (A) nursery and (B) finisher batches from three swine production systems located in the midwestern United States from January 2013 to December 2017.



were 630 and 2436 g, and G:F were 602 and 358 g/kg in nursery and finisher, respectively. These growth responses were reasonably in line with average industry levels for the same time period.

Nursery seasonality

A total of 4960 nursery observations were used in the final model for ADG and 4365 observations were used in the ADFI and G:F models (observations with descriptive variables coded as missing values were unavailable for analysis if the descriptive variables were included in the model; Table 4). Effects of system-flow, size, year, week, fill length, DOE, mortality, sowfarm, and feeder type as well as some of their interactions significantly ($P < .10$) contributed to the variability in growth responses among observations. Parameter coefficients and statistics for each model are provided in the supplementary material. Because there was no evidence of system-flow \times week or size \times week interactions for ADG and ADFI ($P > .10$),

only main effects of week ($P < .001$) were reported. Plots of week of placement least squares means for ADG (Figure 4A) and ADFI (Figure 5A) indicated considerable variation among contiguous weeks. Thus, a rolling average was adopted to describe the seasonal patterns (Figures 4B and 5B), similar to the approach of Bahnsen and Dial.³

Nursery ADG and ADFI progressively decreased as the time of placement transitioned from the 1st to 15th week of the year. Both ADG and ADFI remained low during week 15 to 22 but increased thereafter and became equal to week 1 values by the 43rd and 33rd week of the year, respectively. Interestingly, a second but short period of decrease and recovery in both ADG and ADFI was observed during week 35 to 40 with a diminished magnitude. For G:F, there was no evidence of a week effect in nursery growth performance.

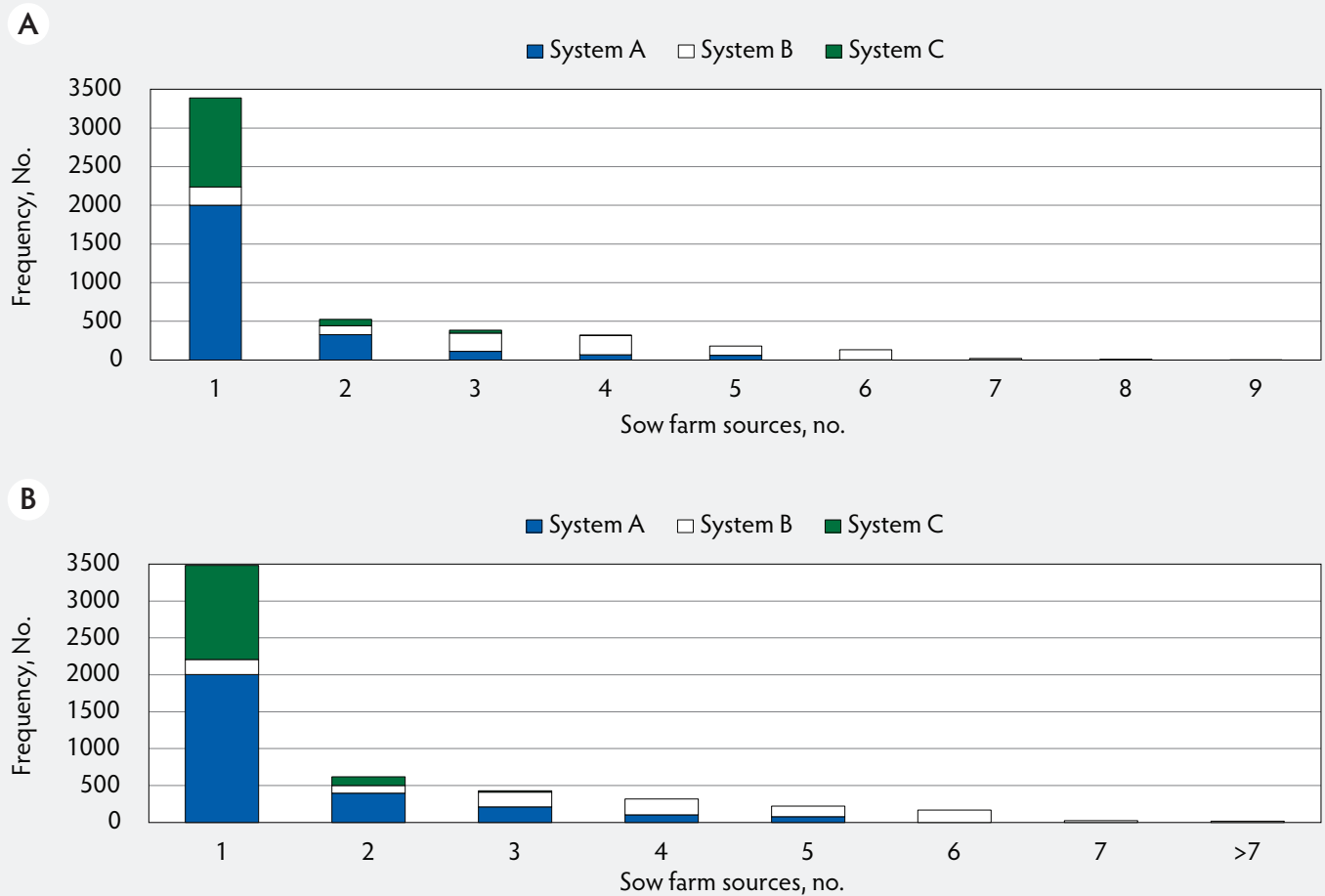
Finisher seasonality

A total of 4747 finisher observations were

used in the final model for ADG and 4743 observations were used in the ADFI and G:F models (Table 5). Effects of system, flow, size, year, week, fill length, initial BW, mortality, sowfarm, feeder, and NE as well as some of their interactions significantly ($P < .10$) contributed to the finisher models. System \times week interactions ($P < .001$) were observed for ADG, ADFI, and G:F (Figures 6, 7, and 8, respectively).

In system A, ADG decreased as the time of placement transitioned from week 1 to 15, remained low from week 15 to 20, and increased thereafter; shortly after a plateau around week 33, a second period of decrease and recovery in ADG was observed during week 33 to 45 with diminished magnitude. In systems B and C, ADG decreased during the first 10 weeks of the year, followed by a period of low ADG from week 10 to 20; thereafter, ADG increased, reached a plateau around week 30, and then decreased to the performance level observed in week 1.

Figure 2: Frequency distribution of number of sow farm sources for (A) nursery and (B) finisher batches from three swine production systems located in the midwestern United States from January 2013 to December 2017.



For ADFI, seasonal patterns were generally similar among systems. Average daily feed intake decreased as the time of placement transitioned during the first 15 weeks of a year, increased for pigs placed from week 20 to 35, reached a plateau, and then decreased to week 1 level. However, the magnitude of the first period of decrease was greater in system B compared with systems A and C (200, 140, and 120 g, respectively). Moreover, the plateau of the ADFI curve remained longer in system C (approximately 15 weeks from week 35 to 50) compared with systems A and B (approximately 7 weeks occurring primarily around weeks 35 to 40).

Distinct seasonal patterns for G:F were observed among systems. In system A, two short periods of G:F decrease and recovery was observed from week 10 to 25 and from week 30 to 50, with the magnitude of decrease smaller during the first than the second period. In systems B and C, G:F increased during the first 20 to 25 weeks of the year and then decreased to the week 1 level by week 35.

Discussion

Seasonal variations have been widely observed in swine production, primarily due to the seasonal changes in environmental temperature.¹⁻³ In this study, we constructed a multi-level linear mixed model that determined the seasonal patterns of ADG, ADFI, and G:F in three US production systems while controlling for variability in growth performance resulting from differences in system, type of pig flow, batch size, year, strategy of barn filling, feeder type, and dietary NE. Because the three systems were generally located nearby and within the midwestern United States, geographic factors were not considered in the model due to data availability and similar seasonal patterns among systems were initially hypothesized. In addition, because genetic information was not available at the batch level for analysis, it was assumed that genetic lines and rate of improvement were consistent within system and the genetic variability could be controlled by the fixed effects of system and year. It is also worth

noting that even though our datasets provided a large number of observations per week (average 95 and 101 batches per week in nursery and finisher datasets, respectively), within-site replication per week was limited because relatively few sites are filled during the same week in multiple years. Therefore, site and week of placement were confounded, which might have contributed to the variability in least squares means among contiguous weeks (Figures 4A, 5A, 6A, 7A, and 8A). However, such differences among week of placement means were not always biologically significant from a production perspective.²

To evaluate the impact of increasing replications over year on the finisher seasonality models, a separate analysis was conducted using five years (2013 to 2017) of finisher data from systems B and C (system A was excluded because of lacking NE data from 2013 to 2014). Seasonality curves generated from the 5-year dataset (data not shown) followed similar patterns as those generated

from the 3-year dataset. Moreover, ventilation design (tunnel versus curtain) was included in the 5-year (systems B and C only) models; there was no evidence that seasonal patterns for finisher growth performance were dependent on ventilation type (data not shown).

In this analysis, there were seasonal patterns in ADG and ADFI for both nursery and finisher datasets. In general, ADG decreased as the time of placement progressed during the first 15 weeks of the year and remained at that level for another 5 to 10 weeks, which was driven by a similar decrease in ADFI. In another retrospective study conducted in 1995, Bahnsen and Dial³ determined the seasonal growth patterns in a commercial swine production system located in the midwestern United States; interestingly, the seasonal changes in finisher ADG and ADFI reported by these authors shared a nearly identical pattern and magnitude as that in system A and was generally in agreement with the other two systems from the present study. It was not surprising that ADG and ADFI decreased as the time of placement

transitioned from winter to spring, because the average ambient temperature likely increased during the corresponding feeding periods. For instance, pigs that were placed in the barn around week 10 to 20 would have experienced the summer weather during June, July, and August, corresponding to the hottest season of a year in that region. It has been well demonstrated that pigs reduce voluntary feed intake in response to high ambient temperature.⁹⁻¹¹ As expected, the seasonal ADG and ADFI curves reached the minimum approximately 5 weeks later in nursery than in finisher due to a shorter feeding length and delayed time of entry during the summer weather. However, finisher growth performance recovered faster than nursery and further increased beyond the week 1 level as the week of placement transitioned into fall (after week 25). Interestingly, a second period of decrease in nursery ADG and ADFI was observed from week 35 to 40; even though the magnitude of this decrease was marginal, it was consistently observed across systems. A similar

pattern was also observed in finishing pigs from system A. Assuming a lactation period of 21 days, nursery pigs that were placed around week 35 to 40 would have been born and nursed during August and might have also experienced in-utero heat stress during June and July. It is possible that extreme temperatures during the summer may have negatively affected late-gestation and lactating sow performance and subsequently decreased growth performance of piglets. Heat stress during late gestation has been demonstrated to decrease the number of piglets born alive and piglet birth weight,¹² and many studies have reported decreased lactating sow feed intake and piglet weaning weight during lactation under heat stress.¹³⁻¹⁵

The magnitude of seasonal variability (difference between the highest and lowest performance of the year) represented approximately 5% of the mean ADG or ADFI in nursery pigs, in contrast to approximately 9% in finisher growth performance. A greater seasonality impact on finisher performance is

Figure 3: Frequency distribution of week of placement for (A) nursery and (B) finisher batches from three swine production systems located in the midwestern United States from January 2013 to December 2017.

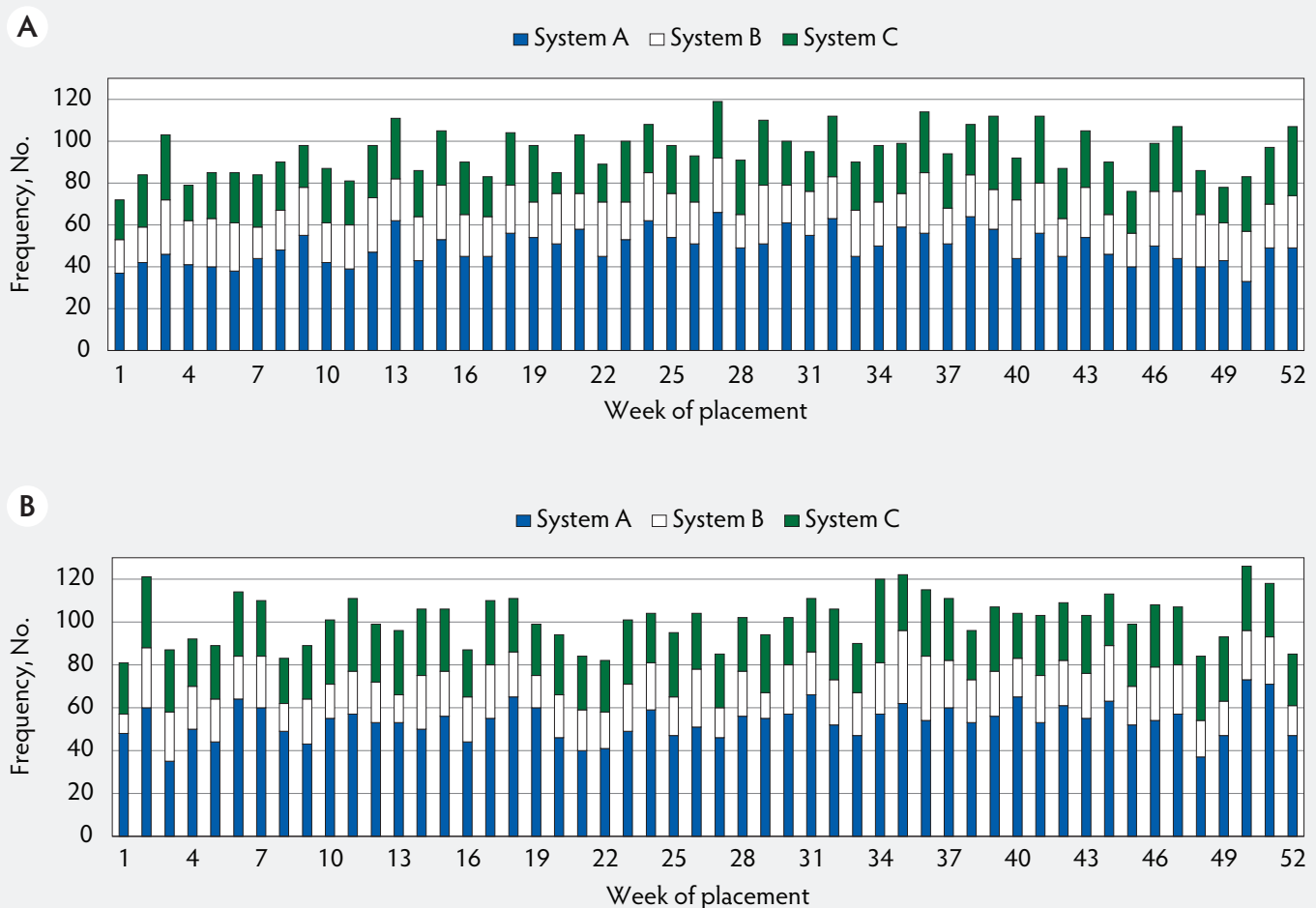


Table 3: Descriptive analysis of explanatory and outcome variables for nursery and finisher batches from three swine production systems located in the midwestern United States from January 2013 to December 2017

Item	N	Mean (SD)	Minimum	Median	Maximum	Industry average*
Nursery dataset						
Initial BW, kg	4960	5.5 (0.49)	2.8	5.4	9.1	NA
Final BW, kg	4960	26.6 (6.71)	8.0	26.2	49.6	23.6
Average DOF, No.	4960	55.3 (12.06)	22.8	53.4	115.2	46.3
Mortality, %	4960	4.1 (4.84)	0.0	2.6	53.4	4.8
ADG, g	4960	370 (67.5)	86	376	603	376
ADFI, g	4846	630 (140.8)	186	617	1270	570
G:F, g/kg	4846	602 (90.4)	185	617	974	660
Finisher dataset						
Initial BW, kg	5269	27.0 (8.1)	10.1	25.9	68.6	NA
Final BW, kg	5269	125.3 (3.87)	101.6	125.3	138.4	128.0
Average DOF, No.	5269	112.4 (14.8)	57.2	114.3	162.2	111.2
Mortality, %	5269	4.0 (2.57)	0.0	3.4	26.3	4.6
Dietary NE, kcal/kg	5191	2626 (144.8)	2423	2577	2949	NA
ADG, g	5269	871 (75.4)	594	862	1347	926
ADFI, g	5264	2436 (229.2)	1769	2413	3683	2386
G:F, g/kg	5264	358 (20.6)	255	359	471	388

* Average of US swine industry productivity from 2013 to 2016.⁸

BW = body weight; NA = not available; DOF = days on feed; ADG = average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio; NE = net energy.

expected because heavier pigs are more sensitive to high ambient temperature and express greater reduction in appetite and growth during the summer compared with nursery pigs.^{1,9} Nevertheless, seasonality effects on G:F were observed in finisher but not in nursery pigs. In systems B and C, G:F increased in finishing pigs fed during the summer. This observation is consistent with findings of another retrospective study using data from nearly 60,000 commercial gilts over 2.5 years, where greater G:F was observed in pigs raised during the summer than winter (357 vs 312 g/kg, respectively).² Improved G:F during the summer may be attributed to the decreased voluntary feed intake and the potential for pigs to utilize less feed for fat deposition (thermal insulation) and maintenance of body temperature.¹⁰ However, it merits further investigation on the reason why system A expressed less seasonal change in G:F compared with systems B and C.

Our models suggest that seasonal patterns for nursery responses were similar among systems and different pig-flow types, while finisher performance patterns were system dependent (system × week interaction). In nurseries, tight regulation of barn temperature and a

relatively consistent diet regimen over time might have resulted in systems sharing similar seasonal patterns. In contrast, for finishers, different systems responded to seasonal change by employing different feeding strategies; for example, a considerable portion of pigs from systems A and C received summer diets with increased dietary NE, while system B did not change dietary NE over season. However, including dietary NE in the finisher models did not fully explain the differences in seasonal patterns among systems. Other factors that might have led to this interaction include management practice, marketing strategy, and other nutritional interventions (eg, addition of ractopamine). Moreover, it is possible that assumptions about the effects of genetic differences and geographical locations are negligible among systems may have been violated and partly contributed to the system × week interaction.

In commercial swine production, application of seasonality curves for growth performance include, but are not limited to, feed usage estimation and marketing projection. Users can predict ADFI of a production batch at the time of placement based on observed ADFI of pigs from a benchmark

week along with the standardized differences among weeks presented as the rolling average curve. Total feed usage of a batch of pigs can be estimated by multiplying the predicted ADFI by pig inventory. Likewise, pig ADG can be estimated at the time of placement and thus the length of feeding period and marketing date can be determined by dividing the difference between targeted market weight and initial BW by the estimated ADG. For more precise estimation of growth responses, users need to adjust for other descriptive factors, eg, pig flow, dietary NE, feeder type, and pig initial BW, using the coefficients presented in the supplementary material.

In addition, caution is needed when applying a uniform seasonality curve to various finisher production systems because seasonal growth patterns of finishing pigs appear to be system dependent (system × week interaction). Systems that share little similarity (eg, geographic location) with the systems studied herein can generate their seasonal growth patterns using the methodology described in this study along with the code for the statistical analysis provided in the supplementary material.

Table 4: Multi-level linear mixed model components for nursery ADG, ADFI, and G:F in three swine production systems located in the midwestern United States from January 2013 to December 2017

Source of variation	P value*		
	ADG (n = 4960)	ADFI (n = 4365)	G:F (n = 4365)
System-flow†	< .001	< .001	< .001
Batch size	< .001	< .001	NS
Year	< .001	< .001	< .001
Week of placement (week)	< .001	< .001	NS
Length of fill period (fill)	.24	.017	NS
Average DOF	< .001	< .001	< .001
Mortality	< .001	< .001	< .001
Number of sow farm sources (sowfarm)	< .001	< .001	NS
Feeder type	NS	< .001	< .001
System-flow × size	NS	< .001	NS
System-flow × year	< .001	< .001	< .001
System-flow × fill	< .001	< .002	NS
System-flow × DOF	< .001	< .001	< .001
System-flow × mortality	< .001	< .001	< .001
Size × year	.004	NS	NS
Size × fill	NS	.02	NS
Size × sowfarm	< .001	< .001	NS

* Multi-level linear mixed models for nursery dataset; model components were selected using a guided stepwise selection method with $P < .10$ considered statistically significant.

† The system and flow variables were merged in the nursery dataset to form a 7-category variable termed system-flow: system A-converted_nursery, system A-nursery, system A-WF_nursery, system B-nursery, system B-WF_nursery, system C-nursery, and system C-WF_nursery.

ADF = average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio; NS = not selected by the model; DOF = days on feed; WF = wean-to-finish.

In summary, this retrospective analysis depicts the seasonal patterns of nursery and finisher growth performance in three commercial swine production systems located in the midwestern United States. Nursery ADG and ADFI expressed prominent seasonal variations and were similar among systems, whereas nursery G:F was not affected by season. Finisher ADG, ADFI, and G:F varied over seasons but the magnitudes and patterns of change were system dependent. This study also presents concepts underlying the implementation of a multi-level linear mixed model of production records to analyze seasonality and potentially other decision factors in commercial systems.

Implications

- Seasonal variabilities in pig growth performance were observed in both commercial nurseries and finishers and can be quantified using a modeling approach based on production records.

- Seasonal patterns for nursery growth performance were similar among investigated systems, while seasonality effects on finisher performance was system dependent.

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Conflict of interest

None reported.

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Figure 4: Effect of week of placement on nursery ADG in three swine production systems located in the midwestern United States from January 2013 to December 2017. Values are presented as (A) least squares means with 95% confidence interval and (B) rolling average (window = 5, step size = 1) for changes in ADG relative to week 1. ADG = Average daily gain.

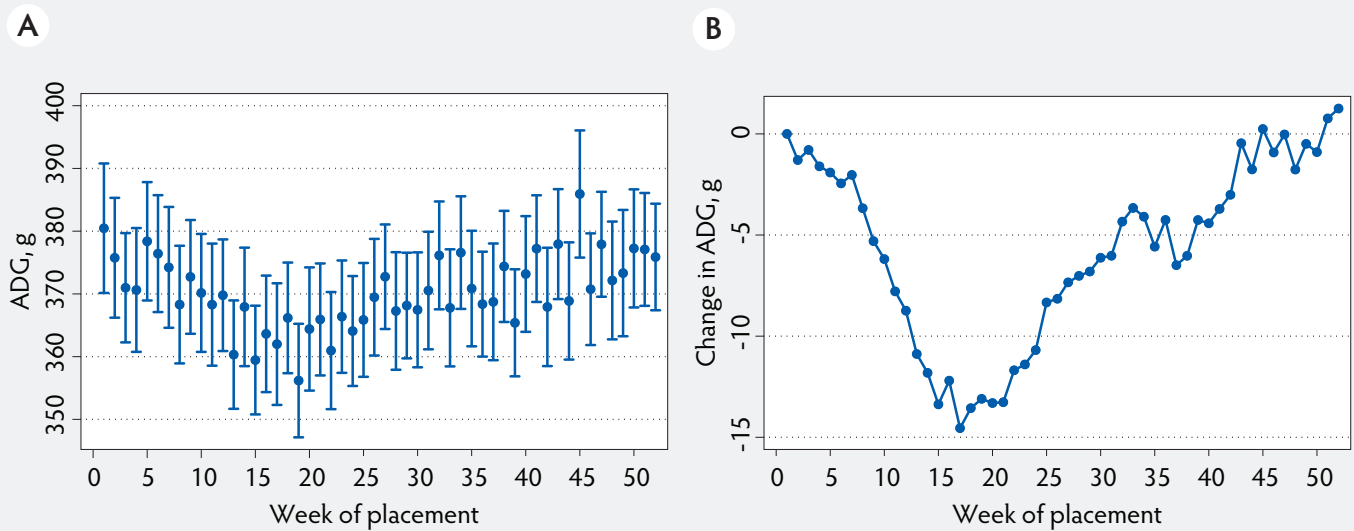
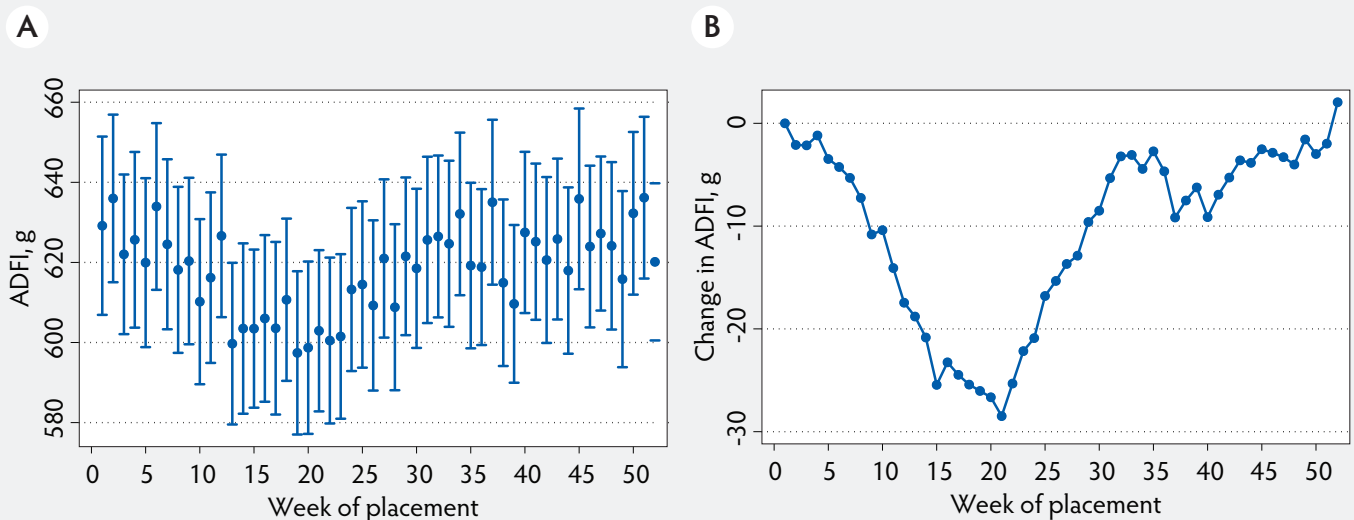


Figure 5: Effect of week of placement on nursery ADFI in three swine production systems located in the midwestern United States from January 2013 to December 2017. Values are presented as (A) least squares means with 95% confidence interval and (B) rolling average (window = 5, step size = 1) for changes in ADFI relative to week 1. ADFI = average daily feed intake.



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Table 5: Multi-level linear mixed model components for finisher ADG, ADFI, and G:F in three swine production systems located in the midwestern United States from January 2015 to December 2017

Source of variation	P value*		
	ADG (n = 4747)	ADFI (n = 4743)	G:F (n = 4743)
System	< .001	< .001	< .001
Flow	.002	.003	< .001
Batch size	.02	.018	.04
Year	< .001	.04	< .001
Week of placement (week)	< .001	< .001	< .001
Length of fill period (fill)	NS	.24	.99
Initial BW	< .001	< .001	< .001
Mortality	< .001	< .001	< .001
Number of sow farm sources (sowfarm)	.68	.11	< .001
Dietary NE	< .001	< .001	< .001
Feeder type	< .001	< .001	NS
System × flow	< .001	< .001	< .001
System × size	< .001	.018	< .001
System × year	.004	< .001	< .001
System × week	< .001	< .001	< .001
System × fill	NS	.095	< .001
System × initial BW	< .001	< .001	< .001
System × mortality	.01	NS	< .001
System × sowfarm	< .001	< .001	NS
System × NE	NS	< .001	< .001
System × feeder	.002	.004	NS
Flow × size	NS	NS	< .001
Flow × year	< .001	< .001	NS
Flow × fill	NS	< .001	NS
Flow × initial BW	.04	NS	NS
Flow × mortality	< .001	< .001	NS
Flow × sowfarm	NS	< .001	< .001
Flow × NE	.015	.002	NS
Size × fill	NS	.01	NS
Size × initial BW	NS	NS	NS
Size × mortality	NS	NS	.09
Size × sowfarm	.007	.006	.006
Size × feeder	NS	< .001	NS

* Multi-level linear mixed models for the finisher dataset; model components were selected using a guided stepwise selection method with $P < .10$ considered statistically significant.

ADG = average daily gain; ADFI = average daily feed intake; G:F = gain to feed ratio; NS = not selected by the model; BW = body weight; NE = net energy.

Figure 6: Effect of week of placement on finisher ADG in three swine production systems located in the midwestern United States from January 2015 to December 2017. Values are presented as (A) least squares means with 95% confidence interval and (B) rolling average (window = 5, step size = 1) for changes in ADG relative to week 1. ADG = average daily gain.

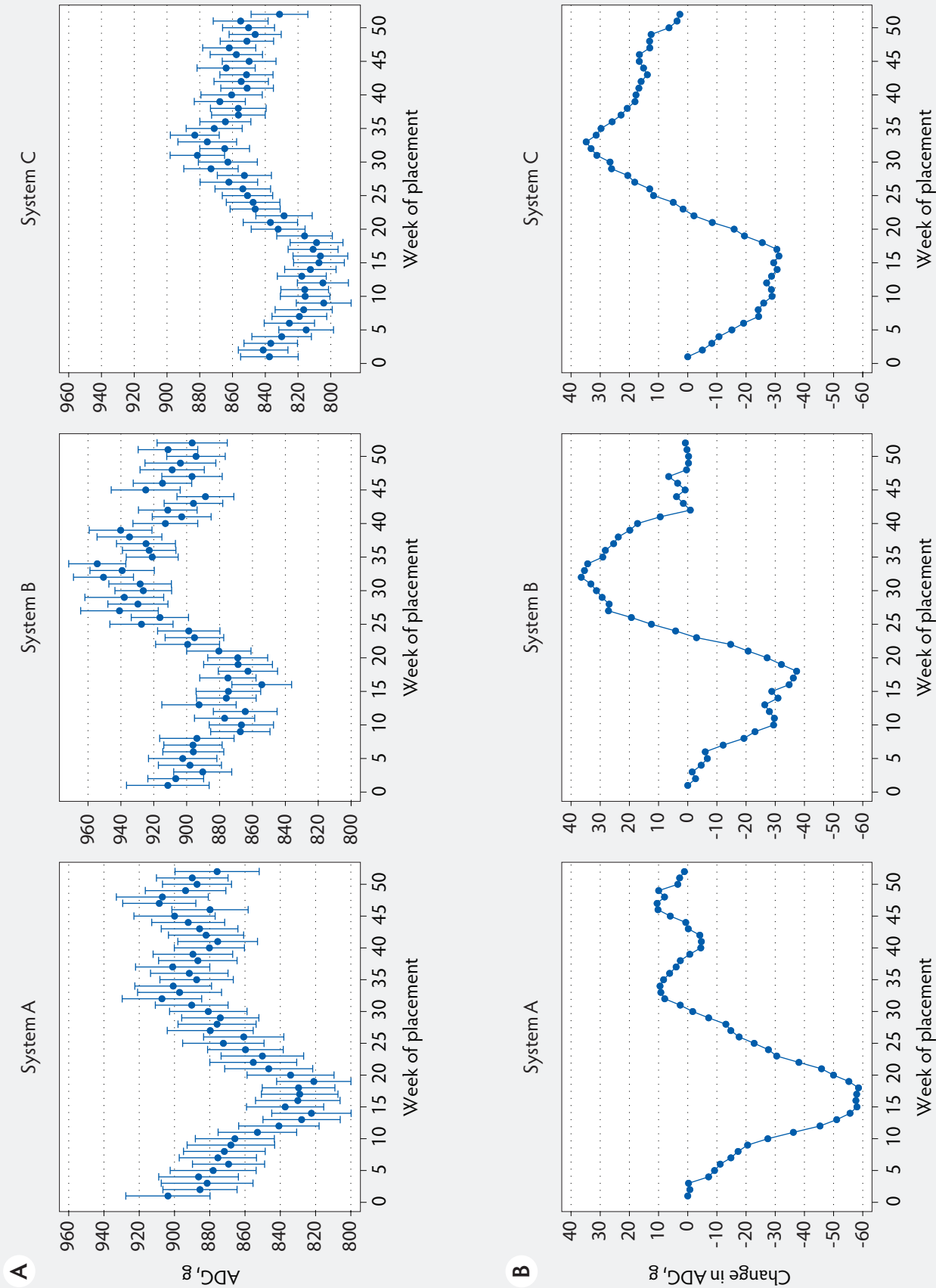


Figure 7: Effect of week of placement on finisher ADFI in three swine production systems located in the midwestern United States from January 2015 to December 2017. Values are presented as (A) least squares means with 95% confidence interval and (B) rolling average (window = 5, step size = 1) for changes in ADFI relative to week 1. ADFI = average daily feed intake.

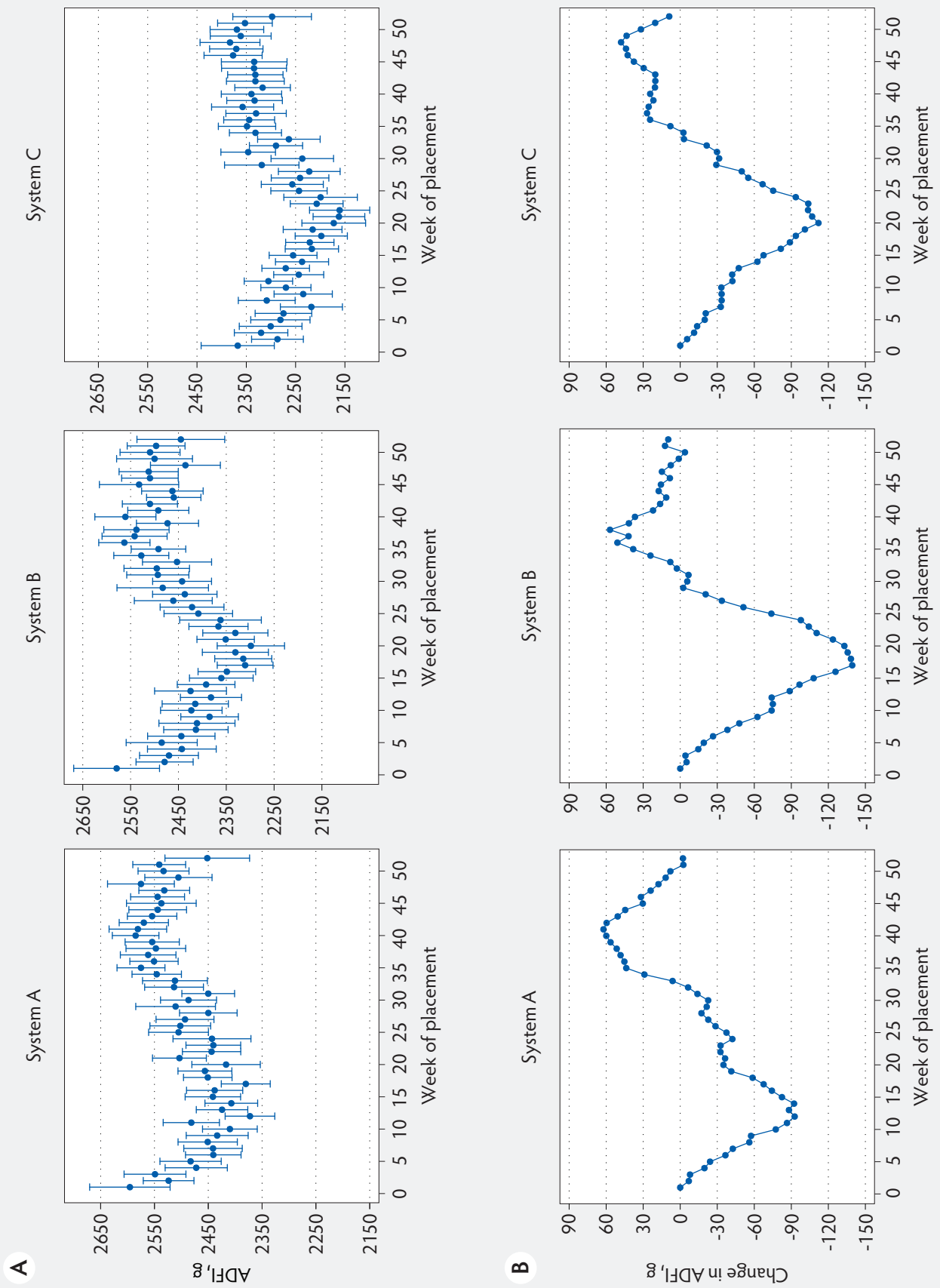
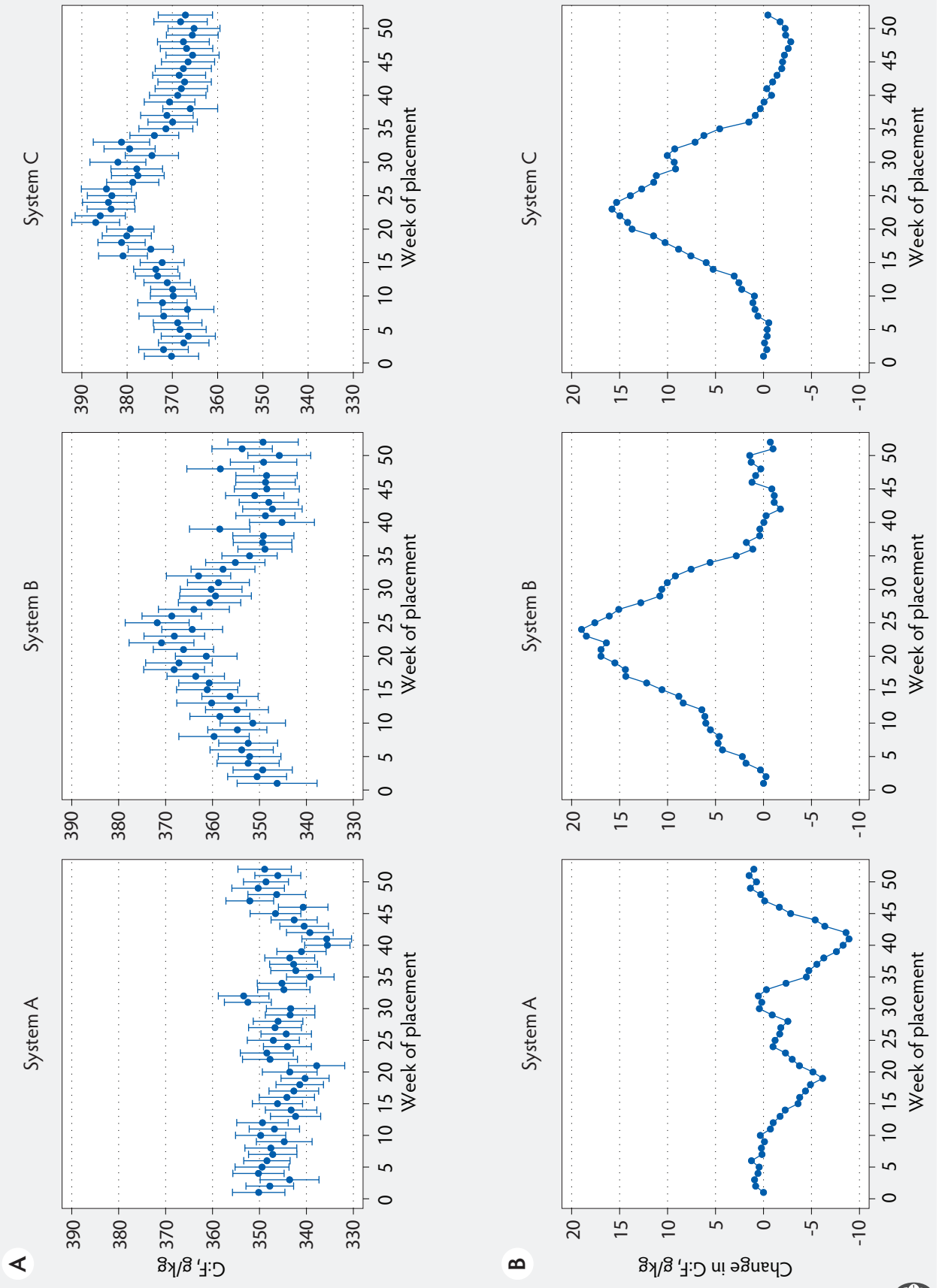


Figure 8: Effect of week of placement on finisher G:F in three swine production systems located in the midwestern United States from January 2015 to December 2017. Values are presented as (A) least squares means with 95% confidence interval and (B) rolling average (window = 5, step size = 1) for changes in G:F relative to week 1. G:F = gain to feed ratio.



Microbiological evaluation of pork offal products collected from processing facilities in a major United States pork-producing region

Alan K. Erickson, PhD; Monte Fuhrman, DVM; William Benjy Mikel, PhD; Jon Ertl, DVM; Laura L. Ruesch, MS; Debra Murray; Zachary Lau, BS

Summary

Analysis of 370 offal samples from 15 US pork-processing facilities detected *Yersinia enterocolitica*-positive (2.4%) and *Salmonella*-positive (21.8%) samples and mesophilic aerobic plate counts > 10⁷ colony-forming units/g (3.2%). A risk assessment showed intestine (20%), brain (21%), liver and heart (73%), and kidney (87%) sampling batches were acceptable for human consumption.

Keywords: swine, offal, *Salmonella*, *Yersinia*, *Toxoplasma*

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Resumen – Evaluación microbiológica de menudencias porcinas recolectadas de centros procesadores en un región importante de producción porcina de los Estados Unidos

El análisis de 370 muestras de menudencias de 15 centros procesadores de cerdo de EUA detectó muestras positivas al *Yersinia enterocolitica* (2.4%) y positivas a la *Salmonella* (21.8%), y conteo de placa aeróbica de mesófilos > 10⁷ unidades/g formadoras de colonias (3.2%). Una evaluación de riesgo mostró que los lotes de muestreo de intestino (20%), cerebro (21%), hígado y corazón (73%), y riñón (87%) eran aceptables para consumo humano.

Résumé – Évaluation microbiologique d'abats de porc prélevés dans des établissements de transformation dans une région de production porcine importante aux États-Unis

L'analyse de 370 échantillons d'abats provenant de 15 établissements de transformation américain a permis de détecter des échantillons positifs pour *Yersinia enterocolitica* (2.4%) et *Salmonella* (21.8%) ainsi que des dénombrements de bactéries mésophiles aérobiques > 10⁷ unités formatrices de colonies/g (3.2%). Une évaluation du risque a démontré que les lots échantillonnés d'intestins (20%), de cerveau (21%), de foie et de cœur (73%), ainsi que de reins (87%) étaient acceptables pour consommation humaine.

Edible offal products from slaughtered hogs represent about 14% of the animal's live weight.¹ These edible offal products include variety meats, which are the edible organs and glands including brain, heart, kidney, liver, thymus gland, and tongue. In the United States, it is estimated that five million metric tons of pork variety meats and other byproducts are generated each year with a large amount of this material being rendered to generate low value products like blood meal, fat, grease, meat and bone meal, and pet food.² An alternative use of US pork offal would be to market

and sell the edible offal products to consumers in countries that prefer strong tasting pork products, like variety meats.³ The desirability of pork offal in foreign markets makes them higher value products in those markets than in the United States, which would likely increase the value of live hogs for US producers.

The purpose of the current study was to determine if pork offal products (brain, heart, intestine, kidney, and liver) as currently produced in US pork-processing facilities are acceptable as food products for human

consumption by worldwide populations. To evaluate the microbiological status of pork offal products, sampling batches of five types of pork offal were tested for general contamination and specific human pathogens including *Salmonella* spp., *Yersinia enterocolitica*, and *Toxoplasma gondii*, which have been identified as three of the most common foodborne hazards in pork.⁴ *Salmonella* spp. and *Y enterocolitica* are normal components of the intestinal microflora of healthy pigs that can easily contaminate other pork products within the processing facility environment.^{5,6} Both *Salmonella* spp. and *Y enterocolitica* cause intestinal infections in humans leading to diarrhea.⁷ Severe *Salmonella* infections, which occur more commonly in young and elderly persons, can lead to bloody diarrhea, vomiting, and rarely death, while severe *Y enterocolitica* infections can cause extraintestinal sequelae, such as reactive arthritis, that can persist for years.⁷ *Toxoplasma gondii* is a protozoan parasite that can infect a variety of porcine organs including brain, heart, and lungs.⁸ *Toxoplasma gondii* causes mild influenza-like symptoms in most infected humans, but it can cause life-threatening infections in fetuses and immunocompromised individuals.⁹

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Erickson AK, Fuhrman M, Mikel WB, et al. Microbiological evaluation of pork offal products collected from processing facilities in a major United States pork-producing region. *J Swine Health Prod.* 2019;27(1):34-38.

Materials and methods

The sampling protocol for this study was based on a risk assessment model designed to determine if the offal products coming from an individual processing facility on a particular sampling day are acceptable for human consumption.¹⁰ In this model, the two criteria used to design the sampling protocol were: 1) level of concern relative to human health hazards of each potential pathogen (eg, indicator, moderate, serious, or severe) and 2) condition of use of the food product (eg, if the food has a preparation step, such as heating, that would reduce microorganism populations).^{10,11} The level of risk to humans for the three pathogens evaluated in this study (*Salmonella* spp., *Y enterocolitica*, *T gondii*) is considered serious based on their ability to cause incapacitating, but not usually life-threatening, disease. To be considered acceptable for human consumption when testing for a serious human pathogen with decreased risk due to inactivation by heating, a sampling batch needs to consist of five samples, all of which need to test negative for the presence of the pathogen.¹⁰ The mesophilic aerobic plate count (APC) is an indicator test of food acceptability¹², with counts less than 1×10^7 colony-forming units/g (CFU/g) considered a negative result. An acceptable APC sampling batch needs to consist of five samples with at least two of the five samples testing negative. Based on this risk assessment model, our sampling protocol included one sampling batch of five types of offal from 15 large pork-processing facilities in ten states (Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Nebraska, North Carolina, South Dakota, and Tennessee) distributed throughout the major pork-producing region of the midwestern and southeastern United States. Selection of slaughterhouses was by convenience, based on proximity to members of the research team. All samples were collected from federally inspected facilities which operate in accordance with the US federal humane slaughter regulations.

Samples of heart, kidney, and liver were obtained from the carcass prior to evisceration or from offal trays depending upon facility operational protocols. An approximately 25-cm segment of ileum was harvested from the intestine just proximal to the ileocecal valve. Brains were harvested by cutting the skull down the median plane using a band saw and then the brain was removed using sterile forceps and placed into a sterile bag.

Five samples (> 400 g each) of each type of offal were collected by placing each sample in a sterile Whirl-Pak bag (Nasco, Fort Atkinson, Wisconsin) minimizing cross contamination as best as possible. Offal samples were obtained every 5 to 10 minutes to ensure that animals from multiple farms were represented in each sampling batch. Immediately upon collection, samples were placed on ice and stored at 4°C prior to shipment for laboratory analysis. Tests for *Y enterocolitica*, *Salmonella*, and APC were initiated within 96 hours of sample collection. Prior to analysis of the intestine samples, the intestinal contents were removed from the lumen by gently squeezing the contents out of the end of the ileum segment. Approximately 100 g of each offal sample were stored at -20°C for *T gondii* detection.

Mesophilic aerobic plate counts were performed by homogenizing 25 g of the minced offal sample in 225 mL of buffered peptone water (BPW) using a Seward 3500 stomacher (Islandia, New York) for 2 minutes at 265 rpm. The resulting tissue homogenate was diluted into BPW using 100-fold serial dilutions. One milliliter of each dilution was pipetted onto a 3M Aerobic Count Petrifilm plate (Maplewood, Minnesota) and allowed to incubate at 37°C for 48 hours. Colonies of aerobic bacteria were counted and the APC was calculated as CFU/g of tissue.

Salmonella spp. detection was performed using a method based on the US Department of Agriculture's Microbiology Laboratory Guidebook.¹³ Minced offal pieces (25 g) were homogenized in 225 mL of BPW using a stomacher for 2 minutes at 265 rpm and then incubated overnight at 37°C. A commercially available real-time polymerase chain reaction (PCR) method that uses a Hygiene BAX analyzer (Hygiene, Camarillo, California) was used to screen for the presence of *Salmonella* DNA. Samples that tested positive for *Salmonella* using PCR were cultured to a pair of selective secondary liquid enrichment media (Hajna Tetrathionate and Rappaport-Vassiliadis Broth; BD, Franklin Lakes, New Jersey) and incubated overnight at 37°C. Ten microliters of each of these broth cultures were spread onto a pair of selective agar plates (XLT and Brilliant Green; BD, Franklin Lakes, New Jersey) and incubated overnight at 37°C. Plates were visually examined to identify potential *Salmonella* spp. colonies.¹³ The identity of each suspected *Salmonella* spp. colony was verified by biotyping using a Bruker Matrix

Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometer (MALDI-TOF MS; Bruker Daltonics, Billerica, Massachusetts).

For detection of *Y enterocolitica*, minced offal samples (25 g) were homogenized in 225 mL of BPW using a stomacher for 2 minutes at 265 rpm. One hundred microliters of the resulting homogenate were spread onto MacConkey and Cefsulodin-Irgasan-Novobiocin (CIN) agar plates (BD, Franklin Lakes, New Jersey) and allowed to incubate at 37°C for 48 hours.¹⁴ The identity of each suspected *Y enterocolitica* colony was verified by biotyping using a Bruker MALDI-TOF MS.¹⁵

While it is known that *T gondii* oocysts are partially inactivated by freezing, the DNA-based PCR assay used in this study is capable of detecting the presence of *T gondii* DNA in frozen tissue.¹⁵ Ten grams of minced, thawed offal were placed into a stomacher bag and 25 mL of cell lysis buffer containing 100 mM Tris hydrochloride (pH = 8.0), 5 mM EDTA, 0.2% sodium dodecyl sulphate, 200 mM sodium chloride, and 40 mg/L proteinase K (30 mAnson U/mg) was added. The sample was homogenized using a stomacher at 265 rpm for 2 minutes and then incubated in a water bath at 55°C for 16 hours to release any *T gondii* oocysts present. The sample was homogenized using a stomacher at 265 rpm for 1 additional minute and then centrifuged for 45 minutes at 3500g. Five milliliters of the supernatant were heated at 100°C for 10 minutes to inactivate proteinase K and then stored at -20°C until PCR testing. The *T gondii* DNA in the samples was amplified and detected using the primers and real-time quantitative PCR method described by Opsteegh et al.¹⁵ A positive control sample of frozen *T gondii*-infected sheep placenta was used to verify that the sample preparation and PCR methods effectively detected *T gondii* DNA in frozen tissue samples.

Results

Of the 370 offal samples, 9 (2.4%) tested positive for *Y enterocolitica*, 81 (21.9%) tested positive for *Salmonella* spp., 11 (3%) had APC > 10^7 CFU/g, and 0 (0%) tested positive for *T gondii* (Table 1). The 9 *Yersinia*-positive samples included 3 of 70 (4.3%) brains, 1 of 75 (1.3%) heart, 1 of 75 (1.3%) intestine, 2 of 75 (2.7%) kidneys, and 2 of 75 (2.7%) livers. The 81 *Salmonella* spp.-positive samples included 25 of 70 (35.7%) brains, 9 of 75 (12%) hearts, 37 of 75 (49.3%) intestines, 2 of 75 (2.7%) kidneys,

Table 1: Percentage of offal samples by type with a positive test for various microbiological pathogens*

Offal type	Samples that tested positive, No. (%)			
	<i>Yersinia enterocolitica</i>	<i>Salmonella</i> spp.	APC > 10 ⁷ CFU/g	<i>Toxoplasma gondii</i>
Intestine (n = 75)	1 (1.3)	37 (49.3)	11 (14.7)	0 (0)
Heart (n = 75)	1 (1.3)	9 (12)	0 (0)	0 (0)
Kidney (n = 75)	2 (2.7)	2 (2.7)	0 (0)	0 (0)
Brain (n = 70)†	3 (4.3)	25 (35.7)	0 (0)	0 (0)
Liver (n = 75)	2 (2.7)	8 (10.7)	0 (0)	0 (0)
Total (N = 370)	9 (2.4)	81 (21.9)	11 (3.0)	0 (0)

* Offal samples were collected from 15 large pork-processing facilities in 10 states distributed throughout the major pork-producing region of the midwestern and southeastern United States.

† One processing plant did not allow the collectors to obtain brain samples.
APC = mesophilic aerobic plate counts; CFU = colony-forming units.

and 8 of 75 (10.7%) livers. All eleven offal samples that had APC > 10⁷ CFU/g were intestine.

Results from APC analysis of brain, heart, kidney, and liver showed that overall contamination of these types of offal was relatively low with 14 of the 15 facilities having APCs that averaged less than 5.0 log₁₀ CFU/g (Figure 1), which is in the normal range for raw meat samples.¹² Average APCs from intestine were much higher than the other types of offal with 10 processing facilities having average APC counts for intestine over 5.0 log₁₀ CFU/g and 6 of those 10 processing facilities having average APC counts for intestine between 6.0 and 7.01 log₁₀ CFU/g. Since none of the sampling batches of offal had 3 of 5 samples with APC counts over 7.0 log₁₀ CFU/g, all offal batches were determined to be acceptable for human consumption based on APC results.

To determine if offal samples produced in a processing facility on a specific day were acceptable for human consumption, the five samples of offal collected from an individual processing facility were considered a sampling batch for risk assessment analysis. In the current study, 68 of 74 (91.9%) sampling batches of all types of offal were acceptable for human consumption based on *Y enterocolitica* testing and 43 of 74 (58.1%) sampling batches were acceptable based on *Salmonella* spp. testing (Table 2). All offal sampling batches were acceptable for human consumption based on APC and *T gondii* testing. All *Yersinia*-positive samples originated from two processing facilities, so 13 of 15 processing

facilities produced five types of offal that were acceptable for human consumption based on *Y enterocolitica* testing. *Salmonella* spp. contamination of offal products was much higher with 31 of 74 sampling batches judged unacceptable. These 31 unacceptable sampling batches included 11 brain, 3 heart, 12 intestine, 2 kidney, and 3 liver. For offal coming from a processing facility to be considered acceptable for human consumption, a sampling batch of offal must pass all four microbiological tests. In this study, 41 of 74 (55.4%) sampling batches passed all four tests. Of these 41 acceptable offal sampling batches, only 3 were brain and 3 were intestine. While both brain and intestine are consumed as human foods in various parts of the world, these two types of offal are not as valuable, based on food product desirability and potential export market price,³ as the other three types of offal tested in this study. When we focus on the higher value offal products, which include heart, kidney, and liver, a higher percentage of sampling batches (35 of 45; 77.8%) passed all four microbiological tests and were acceptable for human consumption.

Discussion

The purpose of the current study was to evaluate the extent of microbiological contamination of edible pork offal as currently processed by large US pork slaughterhouses. This study is not intended to be a comprehensive microbiological survey of all types of pork offal from US pork processors. Of the potential foodborne pathogens tested for in this study, *Salmonella* spp.

contamination represents the biggest impediment to marketing US-produced pork offal products as human foods. A similar study of microbiological status of pork offal products produced by Korean slaughterhouses also identified *Salmonella* as the main foodborne pathogen in pork offal.¹⁶ The type of pork offal that was most commonly contaminated with *Salmonella* spp. was intestine with 12 of 15 sampling batches of intestine determined to be unacceptable for human consumption. Overall, 49.3% of the intestinal samples tested positive for *Salmonella* spp., which is similar to the percentage of *Salmonella*-positive cecal samples detected in market swine (35%) and sows (50%) at US slaughterhouses.¹⁷ Although it is possible for intestines to become contaminated during processing, the prevalence of *Salmonella* spp. in this study's intestinal samples is likely an indication of the percentage of pigs whose intestines (distal ileum) contained *Salmonella* spp. at slaughter. Since the percentage of intestines that naturally contain *Salmonella* spp. is high, US pork-processing facilities that want to market intestine as a human food product, such as chitlins, may benefit from incorporating some type of post-harvest disinfection step, eg, an organic acid wash of the intestinal lumen, to decrease levels of *Salmonella* spp. in these intestinal products.⁷

The other offal products evaluated in this study, including brain, heart, kidney, and liver, are typically sterile at the time of animal slaughter, but can easily become contaminated by microbes during slaughtering, processing, packaging, and storage.¹⁸ The main source of microbial contamination of

Figure 1: Mesophilic aerobic plate counts of offal samples collected from 15 pork-processing facilities in the United States. Offal tissues sampled were brain, heart, kidney, liver, and intestine. APC = mesophilic aerobic plate counts; CFU = colony-forming units.

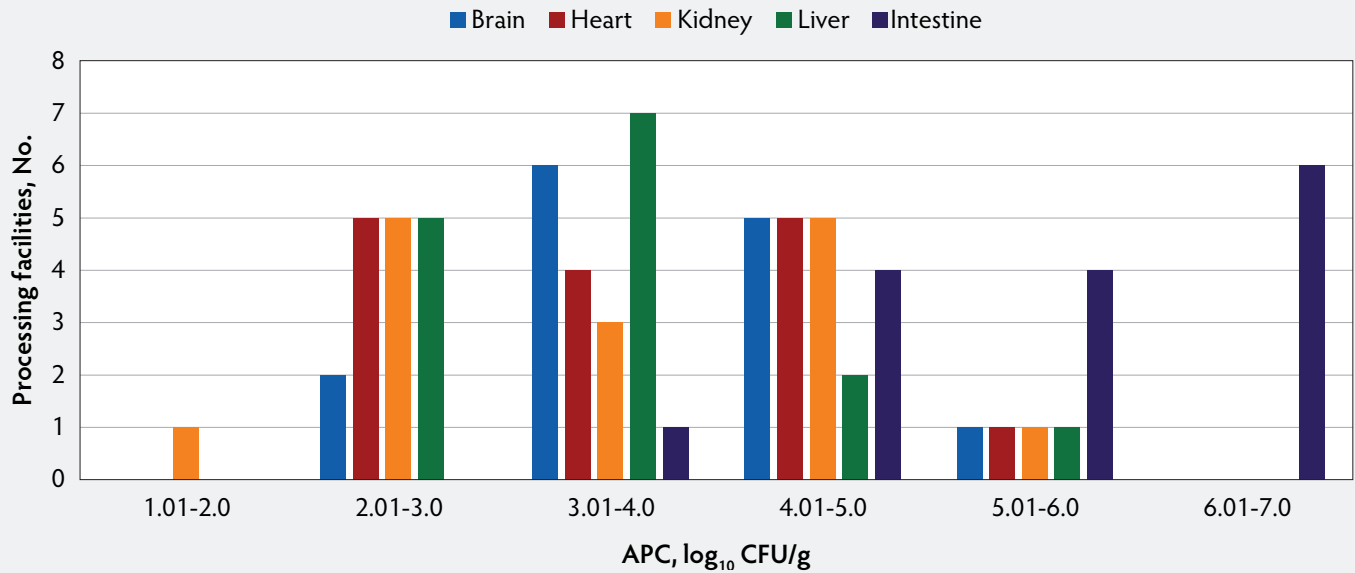


Table 2: Percentage of US pork-processing facilities producing an acceptable sampling batch of each type of offal based on microbiological tests for specific pathogens and APC*

Offal type	US processing facilities producing a sampling batch of offal acceptable for human consumption, No. (%)				
	<i>Yersinia enterocolitica</i>	<i>Salmonella</i> spp.	<i>Toxoplasma gondii</i>	APC	All four tests
Intestine (n = 15)	14 (93.3)	3 (20)	15 (100)	15 (100)	3 (20)
Heart (n = 15)	14 (93.3)	12 (80)	15 (100)	15 (100)	11 (73.3)
Kidney (n = 15)	14 (93.3)	13 (86.7)	15 (100)	15 (100)	13 (86.7)
Brain (n = 14)†	12 (85.7)	3 (21.4)	14 (100)	14 (100)	3 (21.4)
Liver (n = 15)	14 (93.3)	12 (80)	15 (100)	15 (100)	11 (73.3)
Total (N = 74)	68 (91.9)	43 (58.1)	74 (100)	74 (100)	41 (55.4)

* Offal samples were collected from 15 large pork-processing facilities in 10 states distributed throughout the major pork-producing region of the midwestern and southeastern United States.

† One processing plant did not allow the collectors to obtain brain samples.

APC = mesophilic aerobic plate counts.

these offal products in pork-processing facilities comes from tissues, such as intestine, lymph nodes, and tonsils, which are naturally infected with potential foodborne pathogens including both *Salmonella* and *Y enterocolitica*.^{19,20} For example, *Salmonella*-infected intestine can easily become a source of contamination of other tissues at the time of evisceration of the animal, especially if the intestinal wall becomes perforated and the intestinal contents leak onto other tissues, offal trays, processing equipment, or gloves and tools of facility workers.¹¹ Offal products are particularly

vulnerable to this type of contamination since these products are removed from the animal at the same time as the intestine and are then often transported and processed in the same area of the facility as intestine.¹⁶

Other than intestine, the pork offal product that was most highly contaminated with *Salmonella* spp. was brain with 11 of 14 sampling batches determined to be unacceptable for human consumption and 35.7% of brain samples testing positive for *Salmonella*. The likely reason for the high

percentage of *Salmonella*-positive brains is that the harvesting method resulted in contamination. While other offal samples in this study were obtained from the carcass prior to evisceration or from offal trays, the brain samples were harvested from skulls by splitting the skull down the median plane using a band saw and then the brain was removed and placed into a sterile bag using sterile forceps. The blade of the band saw must cut through multiple types of tissues in the skull including the tonsils, which are known to harbor *Salmonella* and is a likely

source of contamination.²⁰ To effectively market brains as a human food, an alternative method for harvest would have to be implemented to minimize contamination during processing.

Microbiological contamination of heart, kidney, and liver was relatively low in the current study with 10 of the 15 processing facilities having no positive *Salmonella* spp. results, and 14 of the 15 facilities having no positive *Y enterocolitica* results. A logical method for further reducing microbial contamination of these types of offal would be to incorporate Hazard Analysis and Critical Control Point (HACCP) systems for processing, packing, transporting, and storing pork offal. The effectiveness of these HACCP programs in reducing contamination of meat products by potential pathogens is demonstrated by 35% of cecal samples from market swine at slaughter testing positive for *Salmonella*, but only 1.2% of retail pork chops testing positive for *Salmonella*.¹⁷ A similar reduction in the *Salmonella* contamination of heart, kidney, and liver would likely occur if HACCP systems for pork offal were implemented at all stages of processing.

Implications

- Heart, kidney, and liver as currently harvested by a majority of US processing facilities tested in this study were acceptable for human consumption based on microbiological evaluation for aerobic bacteria, *Salmonella* spp., *Y enterocolitica*, and *T gondii*.
- Of the three potential foodborne pathogens evaluated in this study, *Salmonella* spp. was the most common contaminant of pork offal products.

Acknowledgements

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Conflict of interest

None reported.

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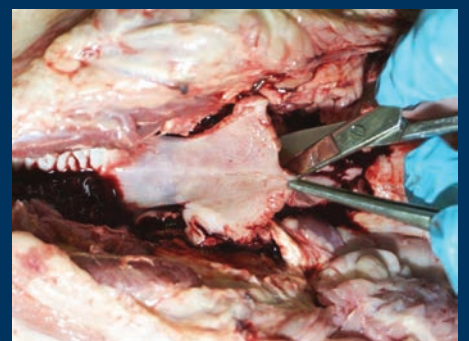
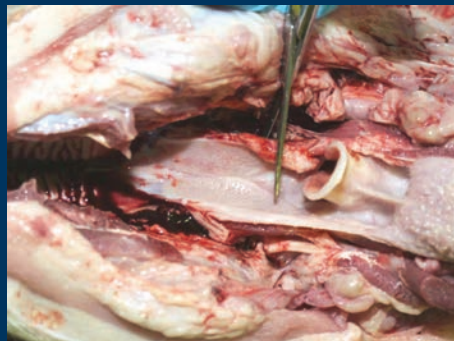
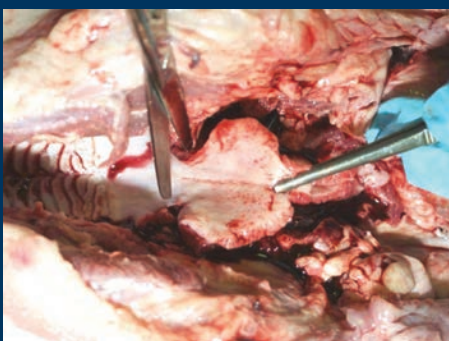
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Foreign animal disease disinfection strategies at pork packing plants

In this Pork Checkoff-funded study, researchers set out to test the efficacy of commercial disinfectants against foreign animal disease (FAD) viruses dried in swine products and on surfaces found in packing plants. An additional goal was to test a less-pathogenic domestic virus as a potential substitute for the foot-and-mouth disease virus (FMDv), which would allow testing outside high-containment laboratories.

Two commonly used disinfectants, CD631 (acid quaternary ammonium-based) and XY12 (sodium hypochlorite-based), were tested against FMDv, classical swine fever virus, and African swine fever virus. Virus-contaminated swine products (blood, meat juice, and feces) dried onto typical packing plant surfaces (stainless steel, plastic, and concrete) were tested. Researchers found both disinfectants were highly effective when the FAD viruses were dried without

organic material on steel and plastic surfaces. Both disinfectants were less effective when FAD viruses were dried in meat juice and blood.

Contaminated swine feces dried on various surfaces could be rapidly disinfected with CD631 and citric acid, however feces strongly inhibited the efficacy of XY12 (sodium hypochlorite-based) disinfectant and bleach. Concrete disinfection was a challenge, but after extensive testing it was determined that commercially sealed concrete had better results. Viruses dried on sealed concrete were inactivated similarly as on the plastic and steel surfaces. Equine rhinitis A virus (ERAv) was used as an FMDv surrogate and responded similarly to CD631 and citric acid disinfectants. However, ERAv was more sensitive than FMDv to disinfection by XY12 and bleach products and was

not a good surrogate, thereby continuing the search for a substitute.

Researchers concluded that acid-based commercial disinfectants such as CD631, used under manufacturer's instructions, are appropriate for disinfection during a FAD virus outbreak. However, surface pre-cleaning steps prior to disinfection are necessary when dry blood products or meat juices are present on surfaces. The hypochlorite-based product (XY12) tested was ineffective at inactivating FAD viruses in the presence of organic material. For more information, go to www.pork.org/research. For a list of EPA-approved disinfectants, go to: www.aphis.usda.gov/animal_health/emergency_management/downloads/fad_epa_disinfectants.pdf.

Illinois farmer named America's Pig Farmer of the Year

Patrick Bane, a pig farmer from Arrowsmith, Illinois, has been named the 2018 America's Pig Farmer of the Year by achieving the highest combined score from a third-party judging panel and online voting. The award recognizes a pig farmer who excels at raising pigs using the We Care ethical principles and who connects with today's consumers about how pork is produced.

"We are pleased to have Patrick represent America's pig farmers. He embodies the very best in pig farming," said Steve Rommereim, National Pork Board president and a pig farmer from Alcester, South Dakota. "It's important that we tell today's consumers how we raise their food in an ethical and transparent way. Patrick's interest in sharing his farm's story, as well as putting a face on today's pig farming, will help us reach this goal."

Raising pigs has been a life-long passion for Bane, whose family has been raising pigs for three generations. Bane raises 74,000 pigs on his farm in central Illinois, where he focuses on protecting public health, hiring the best people and maintaining herd health.

"It's our responsibility to show the public that we are doing the right things to care for our animals and keep them healthy," Bane said. "We need to foster an increased understanding about how food is raised using today's modern technology. It's not only good for us as farmers, but it's good for consumers. You can't drive that point home enough. We have a lot of good, positive stories to share."

To learn more about the program or to nominate someone for the 2019 award, go to www.americaspigfarmer.com.



Improving the performance of porcine reproductive and respiratory syndrome virus oral fluid diagnostics

It is widely accepted that the porcine reproductive and respiratory syndrome virus (PRRSv) can be monitored in swine populations more conveniently, efficiently, and cheaply using oral fluid specimens as compared to surveillance based on testing individual pig serum samples. Oral fluids are a convenient sample to collect, but are often heavily contaminated with feed, feces, and inorganic environmental debris. Attempts to “clean up” samples by centrifugation or filtration have not been effective.

To address this issue, a coagulant formulation that is compatible (does not interfere

or inhibit test performance) with antibody and polymerase chain reaction (PCR)-based testing has been identified. Preliminary results indicate that this formulation could also assist in:

- Cleaning-up and removing particulates from oral fluid samples
- Improving the sample handling characteristics (pipetting) of the sample
- Antibody detection
- Ribonucleic acid detection
- Field application

The goal of this research was to provide a more effective, efficient, inexpensive method of surveillance for prevention, control, or elimination of PRRSv and other economically significant infectious agents affecting the US swine herd.

Researcher: Luis Rodriguez, USDA, Agricultural Research Service, Plum Island Animal Disease Center.

To learn more, go to www.pork.org/research.

Got your premises identification number? It's critical for foreign animal disease preparation

If you don't have a premises identification number (PIN) for every location where you or your clients raise pigs, you need to do so if you want to be fully prepared for a foreign animal disease (FAD). The first step for getting a PIN is to contact your state animal health official's office and talk to the identification program coordinator.

When you are preparing to call your state's identification program coordinator to get your PIN, be prepared to provide the following information for each site:

- Name of entity or company
- Contact information for the owner or other appropriate individual

- Type of operation
- Street address, city, state and ZIP code
- Telephone number
- Some states have an optional category for latitude and longitude numbers
- Most states request the species of livestock on the site

It is important to note that the number of livestock present on the site is not required. The information gathered at the federal level for premises registration is only intended to identify that livestock are present and not the number of animals of each species.



To verify an existing PIN, use the Checkoff's Premises Verification Tool at lms.pork.org/premises.

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

Commodity Leaders Join Forces on Sustainability Research

The National Pork Board, United Soybean Board, and National Corn Growers Association recently signed a memorandum of understanding on a sustainability research platform that will benefit all three organizations and their producers. This research program will include the sharing of completed research, coordination on current and planned research, and define ways to share and communicate results with each organization's members.

Leadership from the three commodity groups agree that it is prudent to consider specific ways in which they might work together more effectively to ensure alignment

and collaboration in sustainability research and how the results can and will be communicated and shared.

“Sustainability is defined by the We Care ethical principles pork producers established over 10 years ago,” said National Pork Board President Steve Rommereim, a pig farmer from Alcester, South Dakota. “Joining in the efforts of two other organizations, as a collective group we can more effectively spend producer dollars to achieve the goals we can all believe in and support. Without one, we wouldn't have the other.”

For more information, contact Brett Kaysen at bkaysen@pork.org or 515-223-2600.



Leaders of the pork, soybean, and corn organizations sign memorandum of understanding on sustainability research.





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AASV announces next Executive Director: Dr Harry Snelson



For the first time in 25 years, the American Association of Swine Veterinarians (AASV) will have a new Executive Director: Dr Harry Snelson. Snelson has had a long association with the organization, starting as the AASV Student Representative at the North Carolina State University College of Veterinary Medicine (NCSU CVM) in 1989. He served on a number of AASV committees and chaired the Foreign Animal Disease Committee before serving two terms on the AASV Board of Directors. He joined the AASV staff as Director of Communications in 2005.

After receiving his DVM degree in 1990, Snelson completed the first Swine Medicine Internship at the NCSU CVM prior to his 10-year tenure as the swine veterinarian for Carroll's Foods in Warsaw, North Carolina. In 2000, he accepted a position as a Swine Technical Services Veterinarian with Schering-Plough Animal Health before leaving in 2003 to become the Director of Science and Technology at the National Pork Producers Council in Washington, DC.

Snelson looks forward to the challenges and opportunities ahead. "It is an honor to

be selected as the Executive Director for AASV," Snelson says. "I am looking forward to continuing to work with Dr Burkgren and learning from him over the next six months. Serving the membership in this role is a responsibility that I will dedicate every effort toward as we move our organization into the future."

In October of 2017, AASV formed a search committee made up of a diverse group of AASV members with a long history of service and leadership to AASV, in addition to hiring an executive search consultant for extensive surveying and interviewing of candidates. The search committee carefully developed a timeline for the nomination, selection, and interviewing of candidates for the Executive Director position from January through September 2018. The final selection was made by the AASV Board of Directors on October 10, 2018, prior to their fall meeting.

A 6-month transition period with both Snelson and Burkgren on staff will occur from October, 2018 through May 31, 2019. During this time, Snelson and Burkgren will work cooperatively to transition responsibilities, along with identifying a new Director of Communications.

Burkgren began his work with AASV in 1994 during a transitional time when the AASV administration was shared with the Iowa Veterinary Medical Association. He was named the first AASV Executive Director in 1997. Under Burkgren's leadership, AASV has grown to a current membership of 1660 representing 48 countries. He has navigated the association through a number of issues including foreign animal and

emerging diseases, animal welfare, judicious drug use, and regulatory and consumer challenges, while always emphasizing our profession's reliance on sound science.

"I congratulate Dr Snelson on being selected as the AASV's second Executive Director," Burkgren says. "It has been my privilege, for the past 25 years, to work with AASV members and with AASV stakeholders to address issues critical to the practice of swine medicine and the swine veterinarian. I am certain that Dr Snelson will continue these efforts at the highest level. The search committee and the AASV Board of Directors are to be commended on the deliberative and forward-thinking process followed during this selection. The Board should also be thanked for committing the resources necessary to provide for a six-month transition period. I look forward to working with Dr Snelson during this period to accomplish a seamless transition by May 31, 2019."

Over the course of AASV's 50-year history, the AASV's Executive Director has played a critical role in providing stability and guidance for the association's volunteer leadership, Dr C. Scanlon Daniels, AASV President, says. "We were fortunate to have enough advance notice to conduct a rigorous search for Dr Burkgren's successor," he adds. "The association owes a debt of gratitude to Dr Burkgren for providing sufficient time to conduct such a thorough search. This also allows our organization an opportunity to smoothly transition the AASV Executive Director responsibilities and identify a new Director of Communications with minimal impact to AASV member services."



FOUNDATION NEWS

Go for the gold!

As AASV prepares to celebrate its golden 50th anniversary, the AASV Foundation Auction Committee is “going for the gold” in an effort to achieve another record-setting auction fundraiser. Auction Chairman Dr Rodney “Butch” Baker encourages AASV members to commemorate the past 50 years by supporting the foundation’s mission to ensure the future for swine veterinarians over the *next* 50 years.

The auction proceeds are a major source of revenue to support foundation programs that include scholarships, swine research

grants, travel stipends for veterinary students, swine externship grants, tuition grants at the Swine Medicine Education Center, American College of Animal Welfare board certification efforts, and more.

Take a look at the items up for bid at www.aasv.org/foundation and make plans to bid on your favorites. With ClickBid mobile bidding, you don’t need to be in Orlando to participate: you can bid on your phone from anywhere! Keep in mind that monetary donations are also welcome and will count towards the total auction proceeds.

It’s easy and fun! And, most importantly, you’ll be supporting the foundation, and the future of swine veterinary medicine, with every dollar you spend, since all the auction items have been donated.

The auction items will be on display in Orlando on auction day, Monday, March 11. It will be “all-in, all-done” for the silent auction at 7 PM Eastern Daylight Time. Be sure to stay for the exciting live auction following the AASV Awards Reception later that evening. We’re counting on your support!

Foundation research proposals due January 18

As part of its mission to fund research with direct application to the profession, the American Association of Swine Veterinarians Foundation is accepting research proposals to be considered for funding in 2019. Proposals are **due January 18, 2019** and may request a maximum of \$30,000 per project. A maximum of \$60,000 will be awarded across two or more projects. The announcement of projects selected for funding will take place at the AASV Foundation Luncheon in Orlando, Florida on Sunday, March 10, 2019. Awardees will be notified in advance.

Proposed research should fit one of the five action areas stated in the AASV Foundation mission statement (see grey sidebar).

The instructions for submitting proposals are available on the AASV Foundation web site at www.aasv.org/foundation/2019/research.php. Proposals may be submitted by mail or email (preferred).

A panel of AASV members will evaluate and select proposals for funding based on the following scoring system:

- Potential benefit to swine veterinarians/swine industry (40 points)
- Probability of success within timeline (35 points)
- Scientific/investigative quality (15 points)
- Budget justification (5 points)
- Originality (5 points)

For more information, or to submit a proposal:

AASV Foundation
830 26th Street
Perry, IA 50220-2328
Tel: 515-465-5255
Fax: 515-465-3832
Email: aasv@aasv.org

AASV Foundation Mission Statement

The mission of the AASV Foundation is to empower swine veterinarians to achieve a higher level of personal and professional effectiveness by:

- enhancing the image of the swine veterinary profession
- supporting the development and scholarship of students and veterinarians interested in the swine industry
- addressing long-range issues of the profession
- supporting faculty and promoting excellence in the teaching of swine health and production
- funding research with direct application to the profession

Swine veterinarians invited to apply for Hogg Scholarship

The American Association of Swine Veterinarians Foundation is pleased to offer the Hogg Scholarship, established to honor the memory of longtime AASV member and swine industry leader Dr Alex Hogg. Applications for the \$10,000 scholarship will be accepted until February 1, 2019, and the scholarship recipient will be announced on Sunday, March 10 during the Foundation Luncheon at the AASV 2019 Annual Meeting in Orlando.

The intent of the scholarship is to assist a swine veterinarian in his or her efforts to return to school for graduate education resulting in a master's degree or higher in an academic field of study related to swine health and production.

Dr Alex Hogg's career serves as the ideal model for successful applicants. After twenty years in mixed animal practice, Dr Hogg pursued a master's degree in veterinary pathology. He subsequently became Nebraska's swine extension veterinarian and professor at the University of Nebraska. Upon "retirement," Dr Hogg

capped off his career with his work for MVP Laboratories. Always an enthusiastic learner, at age 75 he graduated from the Executive Veterinary Program offered at the University of Illinois.

The scholarship application requirements are outlined below, and on the AASV website at www.aasv.org/foundation/hoggscholarship.htm.

Hogg Scholarship Application Requirements

An applicant for the Hogg Scholarship shall have:

1. Three or more years of experience as a swine veterinarian, either in a private practice or in an integrated production setting
2. Five or more years of continuous membership in the American Association of Swine Veterinarians

Applicants are required to submit the following for consideration as a Hogg Scholar:

1. Current curriculum vitae
2. Letter of intent detailing his or her plans for graduate education and future plans for participation and employment within the swine industry
3. Two letters of reference from AASV members attesting to the applicant's qualifications to be a Hogg Scholar

Applications and requests for information may be addressed to:

AASV Foundation
830 26th Street
Perry, IA 50220
Tel: 515-465-5255
Email: aasv@aasv.org



Pigs are not broccoli

Imagine this scenario: a group of people show up at a local hospital exhibiting symptoms consistent with a foodborne illness. The doctors contact the local public health officials who conduct an epidemiological investigation. Laboratory analysis confirms the likely culprit is a *Salmonella* commonly found on livestock farms. The investigation implicates a pork product consumed at a local pig pickin’.

The carcass in question is traced back to a local processor who receives pigs from a number of farms in multiple states. The US Department of Agriculture (USDA) Food Safety Inspection Service (FSIS) is notified and the plant agrees to discontinue processing while an on-site inspection occurs. *Salmonella* contamination is identified by FSIS in multiple areas of the plant.

The Centers for Disease Control and Prevention (CDC) is contacted for assistance in conducting a thorough epidemiological investigation to determine the root cause of the outbreak. The subsequent investigation identifies 5 swine farms in multiple states likely to have provided animals to the plant during the time of the outbreak. Public health officials request access to the farms to conduct an on-farm investigation. This raises several questions and concerns:

- What government agency has the authority to collect samples on the farm?

- What is to be gained by conducting an on-farm investigation?
- What is the farmer’s liability?
- How will processors and consumers respond to a farmer being implicated in an outbreak investigation? Could this limit market access?

In September, I joined representatives from the National Pork Board and the National Pork Producers Council along with other barnyard groups and state animal health officials to discuss these questions and the potential implications of on-farm public health investigations. The USDA-FSIS and Veterinary Services coordinated the two-day meeting. During an outbreak investigation, both animal health officials and public health officials have statutory authority. In most cases, however, public health officials generally rely on state and federal animal health officials to conduct the on-farm investigation and sample collection. The question then becomes, “is an on-farm investigation warranted?”, which was the focus of our meeting. The objective was to begin developing a framework for deciding when on-farm or other pre-harvest investigations are warranted during foodborne outbreaks. The specific goals of the meeting were to:

1. Determine if and when on-farm or other pre-harvest investigations of outbreaks of human illness associated with FSIS-regulated products or animal contact, including those associated with antimicrobial resistant pathogens in animals or animal products, are warranted; and,
2. Develop procedures for such investigations.

Determining the necessity of an on-farm investigation should center around what’s to be learned by collecting samples on the farm and how relevant this information is to the outbreak investigation. For instance, if the pathogen in question is commonly isolated from a farm environment or if there are no additional mitigations that can

“The objective was to begin developing a framework for deciding when on-farm or other pre-harvest investigations are warranted during foodborne outbreaks.”

be put in place at the farm level to address the pathogen in question, is there anything to be gained by conducting an on-farm investigation at a specific farm? Each of the species groups in attendance were asked to consider the circumstances associated with a foodborne illness investigation involving their commodity and outline an algorithm defining the appropriateness of an on-farm response. The discussion within the pork group focused on what was to be gained by such an investigation.

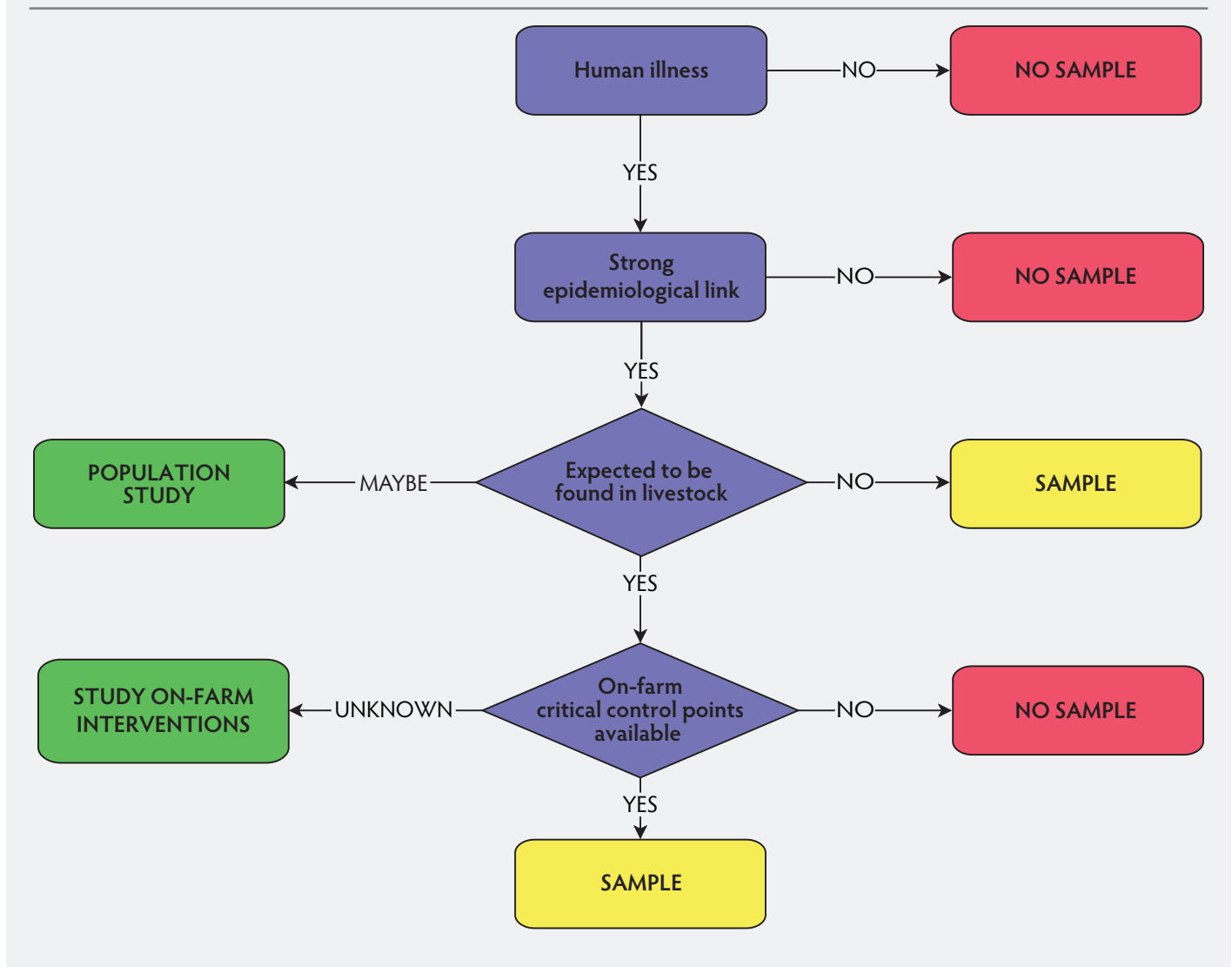
The scenario described above was real. In this case, state and federal public health officials aggressively sought access to the farms supplying hogs to the processing facility implicated in the outbreak even though: 1) the salmonella identified was likely to be found on most swine farms, and 2) the farms also supplied hogs to a number of other processors with no evidence of problems implying that the pathogen exposure was likely the result of contamination at the processor and a failure to properly cook the pork before serving resulting in the disease outbreak. State animal health officials in both states denied requests to conduct on-farm sampling. While it may be a rational decision to deny public health officials access to on-farm sampling, justifying such an action to a broad audience can be a challenge without some previously agreed-upon algorithm defining the criteria to support such a decision.

The pork break-out group, which included pork representatives and state and federal animal health officials, developed a decision matrix (Figure 1) to address the question of when an on-farm investigation is warranted and likely to yield useful information to facilitate future mitigations. The decision points considered included:

- Is there human illness involved?



Figure 1: Decision matrix to determine if an on-farm investigation is warranted.



- Is there a strong epidemiological link to a particular farm or farms?
- Is the pathogen likely to be found on most farms?
- Are there opportunities to implement additional effective mitigations at the farm level?

The responses to these decision points would either support the need for an on-farm investigation, studies into the broader animal population, or the need to investigate the feasibility of implementing on-farm critical control points or additional mitigations.

Although still in draft form, this matrix seems to be a reasonable guideline that could help direct the expectations of farmers as well as state and federal animal and public health officials. This model has been presented to the meeting organizers and will hopefully form the basis for on-going discussions between USDA and CDC. The hope is that this effort will result in the development of memorandums of understanding between the agencies and their state and federal partners describing how these outbreak investigations are to be conducted

going forward. At the very least, these efforts help to increase the awareness of the differences in perception between animal and public health. As one animal health official noted during the meeting, “We need to help public health understand that pigs are not broccoli!”

Harry Snelson, DVM
Director of Communications



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VICE-PRESIDENTIAL CANDIDATE

Dr Mary Battrell

A few years after I graduated from veterinary school, Dr Jim McKean introduced me to his wife by saying “I’d like you to meet Dr Mary Battrell. The faculty at Iowa State University recently worked for her for four years.” I laughed and asked if I was really that demanding. He said, “not at all, you just took advantage of the opportunities in front of you and ensured you got your money’s worth.” What Dr McKean and so many others soon learned was that the questions were not going to slow down. I was just getting started. When I think of all the outstanding members of the American Association of Swine Veterinarians (AASV) who have inspired me, contributed to my professional growth, and helped answer my many questions throughout the years, I am filled with gratitude. The AASV is an exceptional organization. It has an outstanding staff that keeps us all connected and focused. The annual meeting is extremely well organized and provides us multiple tools for improving the health and well-being of our animals while making our producers more profitable. I have received more than my money’s worth from my AASV membership! When asked if I would be a candidate for vice president, my first thought was that I am not the most qualified among the members. I am certainly not the most articulate. I would, however, greatly appreciate the opportunity to show my gratitude and contribute in whatever way possible to further the success of this outstanding organization. I am truly honored to have been nominated for the office of AASV vice president. A sincere thank you to those who nominated me for your confidence and trust. If elected, I will do my best to not disappoint.

I grew up on a diversified crop and livestock farm in southeastern Ohio. I attended The Ohio State University where I earned a bachelor’s degree in agriculture. Immediately following, I earned a master’s degree in animal science from the University of Tennessee. Upon graduation, I moved to Iowa and worked as a sales representative for the Upjohn Company. I decided to pursue my dream and returned to college. In 1995, I earned a doctor of veterinary medicine degree and a master of science degree in

swine production medicine from Iowa State University. Dr Fred Cunningham hired me and gave me the opportunity to gain some valuable production experience. I was a staff veterinarian for Browns of Carolina, a Smithfield-owned hog production company, for three years and a technical services veterinarian for Pharmacia. Although Pharmacia was a wonderful experience, I missed my pigs and people. I returned to production as a staff veterinarian for Smithfield (formerly Murphy-Brown, LLC), where I have remained. I am currently the veterinarian for the East Central Region of Smithfield Hog Production and responsible for the health and well-being of 140,000 sows farrow to finish. I have been actively involved in the development of the Smithfield Animal Care Program and their Contingency Plan for a Foreign Animal Disease. All total, I have been with Smithfield as a field veterinarian for 22 years. Much to my amazement, you were kind enough to award me the 2018 AASV Swine Practitioner of the Year, an honor I will always treasure. I thoroughly enjoy what I do and care deeply for our industry. God has blessed me with a wonderful husband, who is a production director for one of our contract growers, a son-in-law and step daughter with two beautiful boys, and a son who is currently enrolled in animal science at North Carolina State University. Our home has always been filled with love and conversations about pigs.

If elected, I would encourage the AASV to continue their focus on the following key areas:

Providing educational opportunities. We need to ensure that the topics covered at the AASV Annual Meeting and in the e-letter are enticing to its members and provide relevant and timely information. We must maintain our exacting standards and remain a science-based organization.

Prevent disease introductions. Foreign animal and some domestic diseases are a tremendous threat to our industry. Producers are looking to us for answers. We need to educate ourselves and others on identifying risk factors for disease introductions and make every possible effort to mitigate those risks. We need to strengthen our relationships with our state and federal government officials and prepare a contingency plan.



Promote animal agriculture. Much of the general population does not know where their food comes from. They have limited understanding of our business yet are often anxious to offer criticism. We need to constantly look for opportunities for improvement and to share our accomplishments in the areas of animal care, judicious use of antimicrobials, and environmental management. We must continue to strengthen our relationship with the American Veterinary Medical Association and offer increased support to the National Pork Board, National Pork Producers Council, and Swine Health Information Center.

Mentoring students. We need to continue to welcome, nurture, and mentor students. They are the future of this organization and will be the torch bearers for the swine industry.

I have tremendous faith in the membership of the AASV. I believe by working together we will continue to grow and offer improvements for the health and well-being of animals in our care and the producers who depend on us. It would be my privilege to serve as this organization’s next vice president. I would sincerely appreciate your support.





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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.

³ Haugegaard J et al. Effect of supplementing fast-growing, late-weaned piglets twice with 200 mg iron dextran intramuscularly. *The Pig Journal*. 2008; 61: 69-73.

⁴ Olsen C and Fredericks L. Impact of iron dose and hemoglobin concentration on wean-Finish weight gain. *JPVS*. 2018; 910.

UPCOMING MEETINGS

2019 Pig-Group Ski Seminar

February 13-15, 2019 (Wed-Fri)
Copper Mountain, Colorado

For more information:

Pig Group, Lori Yeske
39109 375th Ave, Saint Peter, MN 56082
Tel: 507-381-1647
Email: pyeske@swinevetcenter.com
Web: www.pigski.com

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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Head Office: 9/397 Smith Street
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Australia
Tel: +61 3 8658 9530
Fax: +61 3 8658 9531
Email: rh@asnevents.net.au
Web: www.boarsemen2019.com

Asian Pig Veterinary Society Congress 2019

August 26-28, 2019 (Mon-Wed)
BEXCO, Busan 55, APEC-ro, Haeundae-gu, Busan
Republic of Korea
Tel: +82 51-740-7300

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



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

AASV Industry Support Council

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Nursery pig at University of Missouri Swine Teaching Center.

Photo courtesy of Barbara Molnár Smith

AASV Resources online at www.aasv.org