KSU Swine Day 2016
2016 Swine Day Report

available at:
www.KSUswine.org

• 42 papers
• 47 experiments
• 24,894 pigs
Congratulations!

• Undergraduate Student Achievements
  – Carine Vier - Midwest ASAS 1st oral undergraduate presentation

• Graduate Student Achievements
  – Dr. Jon DeJong - Midwest ASAS Young Scholar
  – Dr. Josh Flohr - Midwest ASAS Young Scholar
  – Annie Clark - Midwest ASAS 1st place MS oral presentation and K-State Donoghue Graduate Scholarship
  – Lori Thomas - 1st place MS poster presentation, Pinnacle Award (International Ingredients Corp.) and Feed Energy Scholarship
  – Jordan Gebhardt - Midwest ASAS 1st place PhD poster presentation
Congratulations!

• Graduate Student Achievements
  – Dr. Loni Schumacher, ASAS Midwest NPB Innovation Abstract award
  – Corey Carpenter – K-State Presidential Doctorial Scholarship and Feed Energy Scholarship
  – Rodger Cochrane - K-State Presidential Doctorial Scholarship
  – Arkin Wu - Bob and Karen Thaler Graduate Student Swine Nutrition Scholarship
  – Mariana Menegat – Leman Conference – Best paper award

• Alumni Achievements
  – Casey Neill - ASAS Midwest Early Career Agribusiness Award
Feed Mill Biosecurity

Cassie Jones
Jason Woodworth
Kansas State University

November 17th, 2016
K-State Swine Day
What is the value of safe feed?

Chart 4 - PED EWMA Analysis for years 2013 - 2017

- EWMA weekly % cases of at risk
- Epidemic Threshold
- Actual

Key dates:
- 9/4/13
- 12/31/14
- 11/4/15
What is the value of safe feed?

Adjusted Feed Conversion Ratio

- Formula Change
- New Mill Management
- New Ingredient Supplier
Feed Mill Biosecurity

Swine Health Producer Guide

The Role of PEDV in Feed: Current Knowledge and Understanding

Roger Cochrane and Dr. Cassie Jones, Department of Grain Science and Industry, Kansas State University

Reviewers: Scott Deck, Joel DelRousse, Steve Dritz, Phillip Gauger, Laura Gremel, Anne Huss, Eric Nelson, Mike Tokach, Henry Turpentine, Pedro Urriola, and Jason Woodworth

Commentary

Feed mill biosecurity plans: A systematic approach to prevent biological pathogens in swine feed

Roger A. Cochrane, MS; Steve S. Dritz, DVM, PhD; Jason C. Woodworth, MS, PhD; Charles R. Stark, MS, PhD; Anne R. Huss, MS, PhD; Jean Paul Cano, DVM, PhD; Robert W. Thompson, DVM, MS; Adam C. Fahrenholz, MS, PhD; Cassandra K. Jones, MS, PhD

Summary

Development of a feed mill biosecurity plan through a number of means, including ingredients, manufacturing equipment, or people, and sanitation procedures. The objective of this review is to describe biological hazards that may be present in swine feed locations.
Feed Mill Biosecurity

**Prevention**
- Receiving procedures
- Dust control
- Personnel zoning
- Flushing and sequencing

**Intervention**
- Point-in-time
  - Thermal processing
  - Radiation
  - Chemical additive application

**Postvention**
- Facility decontamination
Feed Mill Biosecurity

Prevention

- Receiving procedures
- Dust control
- Personnel zoning
- Flushing and sequencing
Feed Mill Biosecurity

- Do **NOT** add dust back to feed to save on shrink
- Control traffic
Feed and feed equipment surface Ct values

Schumacher et al., 2015
Sequencing to prevent PEDV infectivity

<table>
<thead>
<tr>
<th>Item</th>
<th>Feed inoculum</th>
<th>0 dpi</th>
<th>2 dpi</th>
<th>4 dpi</th>
<th>6 dpi</th>
<th>7 dpi</th>
<th>Cecum</th>
</tr>
</thead>
<tbody>
<tr>
<td>After non-PEDV feed</td>
<td>Neg</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
</tr>
<tr>
<td>After PEDV feed</td>
<td>Pos</td>
<td>0/9</td>
<td>9/9</td>
<td>9/9</td>
<td>9/9</td>
<td>9/9</td>
<td>9/9</td>
</tr>
<tr>
<td>After Sequence 1</td>
<td>Pos</td>
<td>0/9</td>
<td>1/9</td>
<td>3/9</td>
<td>3/9</td>
<td>3/9</td>
<td>3/9</td>
</tr>
<tr>
<td>After Sequence 2</td>
<td>Neg</td>
<td>0/9</td>
<td>1/9</td>
<td>3/9</td>
<td>3/9</td>
<td>3/9</td>
<td>3/9</td>
</tr>
<tr>
<td>After Sequence 3</td>
<td>Neg</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
</tr>
<tr>
<td>After Sequence 4</td>
<td>Neg</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
<td>0/9</td>
</tr>
</tbody>
</table>

A total of 3 replications/treatment with 3 pigs/replicate

- Sequencing reduced PEDV detection in feed
- However, carry over of infectivity did occur

Schumacher et al., 2015
# Flushing to prevent PEDV infectivity

<table>
<thead>
<tr>
<th>Item</th>
<th>Untreated</th>
<th>Formaldehyde</th>
<th>2% MCFA</th>
<th>10% MCFA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prevalence, % positive</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative feed</td>
<td>0/3</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Positive feed</td>
<td>3/3</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Laboratory scale mixer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice hull flush</td>
<td>3/6</td>
<td>1/6</td>
<td>2/6</td>
<td>0/6</td>
</tr>
<tr>
<td>Subsequent feed</td>
<td>0/6</td>
<td>0/6</td>
<td>0/6</td>
<td>0/6</td>
</tr>
<tr>
<td><strong>Production scale mixer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice hull flush</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>0/3</td>
</tr>
<tr>
<td>Subsequent feed</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>0/3</td>
</tr>
<tr>
<td><strong>Production scale bucket elevator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice hull flush</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>1/3</td>
</tr>
<tr>
<td>Subsequent feed</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>0/3</td>
</tr>
</tbody>
</table>
Feed Mill Biosecurity

**Intervention**
- Point-in-time
- Thermal processing
- Radiation
- Chemical additive application
# Pelleting to Reduce PEDV

Number of Pigs Infected with PEDV by Bioassay

<table>
<thead>
<tr>
<th>Feed</th>
<th>0 dpi</th>
<th>2 dpi</th>
<th>4 dpi</th>
<th>6 dpi</th>
<th>7 dpi</th>
<th>7 dpi Cecum</th>
</tr>
</thead>
<tbody>
<tr>
<td>No PEDV</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100°F</td>
<td>9/9</td>
<td>0</td>
<td>1/9</td>
<td>3/9</td>
<td>3/9</td>
<td>3/9</td>
</tr>
<tr>
<td>130°F</td>
<td>9/9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>145°F</td>
<td>8/9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>160°F</td>
<td>8/9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Infectivity developed in diets pelleted below 130°F

Cochrane et al., 2015
Complete Diet

- Untreated control
- Medium chain fatty acid
- Commercial formaldehyde

All effects and interactions, $P < 0.0001$

Quantitative CT Value

Day

Cochrane et al., 2015
Spray-Dried Animal Plasma

Quantitative CT Values

- Untreated control
- Medium chain fatty acid
- Commercial formaldehyde

All effects and interactions, $P < 0.0001$

Cochrane et al., 2015
Medium Chain Fatty Acids

• Antiviral properties
  – Bind with cell membrane proteins
  – Incorporation into the cell membrane
  – Causes destabilization of the cell membrane bi-layer

Xue and Xiao, 2015
Complete Diet

Quantitative CT Values

- Commercial formaldehyde
- MCFA 1%
- MCFA 2%
- Positive

All fixed effects and interactions $P < 0.01$

Bioassay

Cochrane et al., 2016
Spray-Dried Animal Plasma

- Commercial formaldehyde
- MCFA 1%
- MCFA 2%
- Positive

Quantitative CT Value

All fixed effects and interactions $P < 0.01$

Cochrane et al., 2016
Synthetic MCFA Sources

- PEDV +
- SalCurb
- 1% MCFA
- C6
- C8
- C10
- C12
- C10-C12

Quantitative CT Value vs. Day

Cochrane et al., 2016
Natural Fat Sources

- **PEDV +**
- 1% Soy Oil
- 1% Canola Oil
- 2% Palm Kernel Oil
- 1% Palm Kernel Oil
- 1% Coconut Oil
- 2% Coconut Oil

Quantitative CT Value vs. Day

Cochrane et al., 2016
## PEDV Infectivity of Synthetic and Natural Fat Sources

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CT Value</th>
<th>Infectivity of d3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEDV Positive</td>
<td>31</td>
<td>+</td>
</tr>
<tr>
<td>SalCURB</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>MCFA Blend</td>
<td>37</td>
<td>-</td>
</tr>
<tr>
<td>C6</td>
<td>36</td>
<td>-</td>
</tr>
<tr>
<td>C8</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>C10</td>
<td>34</td>
<td>-</td>
</tr>
<tr>
<td>C12</td>
<td>33</td>
<td>+</td>
</tr>
<tr>
<td>Palm Kernel Oil</td>
<td>31</td>
<td>+</td>
</tr>
<tr>
<td>Coconut Oil</td>
<td>32</td>
<td>+</td>
</tr>
<tr>
<td>Choice White</td>
<td>31</td>
<td>+</td>
</tr>
<tr>
<td>Soy Oil</td>
<td>30</td>
<td>+</td>
</tr>
<tr>
<td>Canola Oil</td>
<td>31</td>
<td>+</td>
</tr>
</tbody>
</table>

No Infectivity until d 7

Cochrane et al., 2016
Feed Mill Biosecurity

Postvention

- Facility decontamination

K-State Research and Extension
Environmental contamination after processing PEDV-inoculated feed

Zone 1 = direct feed contact surfaces - equipment interiors
Zone 2 = surfaces directly adjacent to zone 1
Zone 3 = structural surfaces - floors, walls

Schumacher et al., 2015
PEDV Decontamination of Surfaces

- Surfaces inoculated with 1 mL liquid PEDV 19338E P8 104 (CT 20.8), dried in biosafety cabinet before treatment application (Bowman et al., 2015)
- 5 Different Surfaces (25.8 cm²)
- 15 g of dry or 1 mL of liquid applied to surface
- After 15 min, surfaces tapped to remove treatment
- Surface swabbed
- Swabs analyzed via qRT-PCR analysis
Effect of surface type on PEDV (Positive Controls)

Surface × Treatment $P = 0.001$

<table>
<thead>
<tr>
<th>Surface</th>
<th>CT Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>27.5</td>
</tr>
<tr>
<td>Plastic</td>
<td>26.7</td>
</tr>
<tr>
<td>Rubber</td>
<td>23.8</td>
</tr>
<tr>
<td>Steel</td>
<td>24.6</td>
</tr>
<tr>
<td>Tote bag</td>
<td>28.3</td>
</tr>
</tbody>
</table>

Muckey et al., 2016
Effect of sanitizer type on steel

Surface × Treatment $P = 0.001$
Dry vs. Liquid $P < 0.0001$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>PEDV RNA (CT-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive control</td>
<td>24.6</td>
</tr>
<tr>
<td>Untreated rice hulls</td>
<td>24.5</td>
</tr>
<tr>
<td>Treated rice hulls</td>
<td>24.5</td>
</tr>
<tr>
<td>Formaldehyde product</td>
<td>45</td>
</tr>
<tr>
<td>Benzoic acid and probiotic</td>
<td>26.3</td>
</tr>
<tr>
<td>Food-grade sanitizer</td>
<td>26</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>27.2</td>
</tr>
<tr>
<td>Quaternary product</td>
<td>27.3</td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>37.1</td>
</tr>
<tr>
<td>MCFA</td>
<td>26</td>
</tr>
</tbody>
</table>

Muckey et al., 2016
Effect of sanitizer type on cement

Surface × Treatment $P = 0.001$
Dry vs. Liquid $P < 0.0001$

PEDV RNA (CT-value)

- Positive control
- Untreated rice hulls
- Treated rice hulls
- Formaldehyde product
- Benzoic acid and probiotic
- Food-grade sanitizer
- Hydrogen peroxide
- Quaternary product
- Sodium hypochlorite
- MCFA

Muckey et al., 2016
Take Home Messages

• Place as many prevention/interventions in feed mills as is economical and practical
  – Receiving procedures
  – Restrict traffic flow
  – Dust control
  – Flushing/sequencing
  – Pelleting
  – Chemical additives (commercial formaldehyde, 1% MCFA)

• Decontamination of mills is a challenge
  – Nearly all surfaces get contaminated by dust
  – Requires liquid sanitizing
Thank You!

Commentary

Feed mill biosecurity plans: A systematic approach to prevent biological pathogens in swine feed

Roger A. Cochrane, MS; Steve S. Dritz, DVM, PhD; Jason C. Woodworth, MS, PhD; Charles R. Stark, MS, PhD; Anne R. Huss, MS, PhD; Jean Paul Cano, DVM, PhD; Robert W. Thompson, DVM, MS; Adam C. Fahrenholz, MS, PhD; Cassandra K. Jones, MS, PhD

Summary
Development of a feed mill biosecurity plan can minimize risk of introduction of biologic hazards and limit potential economic losses from animal or human pathogens such as Salmonella and porcine epidemic diarrhea virus. A biosecurity plan should be detailed and contain hazard controls at each step of the manufacturing process. Biologic hazards can cause illness or injury in humans or animals. These hazards can be introduced through a number of means, including ingredients, manufacturing equipment, or people, so controls must aim to prevent or reduce their prevalence. The Food Safety Modernization Act requires most feed mills to identify and control hazards. A biosecurity plan can serve as an effective prerequisite program to reduce the likelihood of a biological hazard occurrence by identifying ingredient specifications, sampling methods, analytical procedures, receiving guidelines, equipment cleanout, production parameters, load-out, and sanitation procedures. The objective of this review is to describe biological hazards that may be present in swine feed, locations of their potential entry, and suggested practices for a successful biosecurity plan for feed mills manufacturing swine feed.

Keywords: swine, feed, biosecurity, hazard analysis, pathogen control

Received: October 26, 2015
Accepted: December 2, 2015

May/June 2016
Journal of Swine Health and Production
Feed Mill Quality Control
Particle Size Analysis
Uniformity of Mix

Charles Stark
New Extension Bulletin

Evaluating Particle Sizes

As grain accounts for a major component and cost in diets for feedlot animals, the particle size of grains influences feed digestibility, feed efficiency, mixing performance, and palatability. Therefore, particle size evaluation is a necessary component of a feed manufacturing quality assurance program and recommended by nutritionists. The purpose of this bulletin is to describe the equipment, procedure, costs, and interpretation of particle size analysis.

The standard for particle size analysis by sieving is published by the American Society of Agricultural and Biological Engineers (ASABE). As stated in their publication, “Methods of determining and expressing fineness of feed materials by sieving (ASABE SS-71 A PBE 2000 R2002l),” the purpose of this standard is to define a test procedure to determine the fineness of feed ingredients and to define a method of expressing the particle size of the materials.

The standard allows several variations for the testing procedure. Specifically, it allows the use of different sieve shakers, such as a Tyler type, Rotoch or equivalent unit.

It also allows optional use of sieve agitators, such as small rubber balls and sieve plate discs to help move particles around on sieve shakers. Another option is whether a flow agent is used to help move material down (sifting or sieving agents) through the sieves.

Finally, the time of sieving can range from 10 to 15 minutes in the official procedure. Research indicates slight differences in particle size and distribution results because they use different variations. Research has been performed on differences in particle size and distribution resulting from differences in methodology (Khalilova et al., 2015; Stark and Cheung, 2011; Palmezani et al., 2008). Their studies found that the use of a shaker, use of agitators and sieving agent influenced the particle size and the variation in particle size measured (Table 1).

A significant difference due to time was found for particle size when sieve agitation and sieving agents were used together (Khalilova et al., 2015). Figure 1 depicts the difference in the amount of each size (15.4 mm to 0.15 mm) achieved.

Available at:
www.KSUswine.org
Particle Size Analysis - Method

• ANSI/ASAE Method S319.4 (2012)
  “Method of determining and expressing fineness of feed materials by sieving”
• Procedure:
  – 100 ± 5 gram sample
  – Ro-tap for 15 minutes (10 minutes S319.2)
• Sieving agents (options)
  – Sieve agitators
  – Dispersing or flow agents
• $d_{gw}$ – geometric mean diameter
  – Units = microns
• $S_{gw}$ – geometric standard deviation
  – No units - S319.2
  – Microns – S319.4
Particle Size Analysis

Step #1 Split Sample

Step #2 Weigh 100 g

Step #3 Rotap 15min

Step #4 Record Weight on Sieve
Ro-Tap Machine

- Bar taps while circularly rotating
- Screen size opening decreases from top to bottom in sieve stack
- Particles continue moving down sieve stack until the sieve opening is smaller than the particle
### Sieve and Sieve Agitator Arrangement

<table>
<thead>
<tr>
<th>U.S. Sieve No.</th>
<th>Sieve Opening (µm)</th>
<th>Sieve Agitator(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>3360</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>2380</td>
<td>None</td>
</tr>
<tr>
<td>12</td>
<td>1680</td>
<td>Three Rubber Balls</td>
</tr>
<tr>
<td>16</td>
<td>1190</td>
<td>Three Rubber Balls</td>
</tr>
<tr>
<td>20</td>
<td>841</td>
<td>Three Rubber Balls</td>
</tr>
<tr>
<td>30</td>
<td>595</td>
<td>One Rubber Ball; One Brush Agitator</td>
</tr>
<tr>
<td>40</td>
<td>420</td>
<td>One Rubber Ball; One Brush Agitator</td>
</tr>
<tr>
<td>50</td>
<td>297</td>
<td>One Rubber Ball; One Brush Agitator</td>
</tr>
<tr>
<td>70</td>
<td>210</td>
<td>One Rubber Ball; One Brush Agitator</td>
</tr>
<tr>
<td>100</td>
<td>149</td>
<td>One Brush Agitator</td>
</tr>
<tr>
<td>140</td>
<td>105</td>
<td>One Brush Agitator</td>
</tr>
<tr>
<td>200</td>
<td>74</td>
<td>One Brush Agitator</td>
</tr>
<tr>
<td>270</td>
<td>53</td>
<td>One Brush Agitator</td>
</tr>
<tr>
<td>Pan</td>
<td>-</td>
<td>None</td>
</tr>
</tbody>
</table>

*Goodband et al. (2006)*
Sieve Agitator

Plastic

Brushes

Rubber Balls
Method Options

Sieve Agitator

Dispersing/Flow Agent
Effect of No Dispersion/Flow Agent

Kalivoda, 2015
Means for Particle Size

Method $P<0.0001$

Kalivoda, 2015
Means for Standard Deviation

Method $P<0.0001$

Kalivoda, 2015
Sample Distribution

U.S. Sieve Number

Weight, g

Sample with Sieving Agent¹  Sample without Sieving Agent²

¹dgw: 402 µm; Sgw (S319.2): 3.11; Sgw (S319.4): 561 µm;
²dgw: 448 µm; Sgw (S319.2): 2.50; Sgw (S319.4): 470 µm;
Results of Mix Time

%CV

Mix Time

2 min 3 min 5 min 15 min 30 min 45 min 60 min

Saensukjaroenphon, 2016
Results of Salt Particle Size and Sample Preparation

Salt particle size × Sample preparation $P=0.0002$

%CV

Salt Particle Size

- Fine
- Medium
- Coarse

Salt Particle Size

- Unground
- Ground

Saensukjaroenphon, 2016
# Results of Wet Mix Time and Nozzle

![Results graph]

### Wet Mix Time
- **15 sec**
- **30 sec**
- **45 sec**

### Nozzle
- **Spray tip**
- **Without spray tip**

<table>
<thead>
<tr>
<th>Wet Mix Time</th>
<th>Nozzle</th>
<th>%CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 sec</td>
<td>A</td>
<td>23</td>
</tr>
<tr>
<td>30 sec</td>
<td>A, B</td>
<td>15</td>
</tr>
<tr>
<td>45 sec</td>
<td>B</td>
<td>10</td>
</tr>
<tr>
<td>Spray tip</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Without spray tip</td>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>

*P = 0.0055*

Linear *P = 0.0016*

Saensukjaroenphon, 2016
Electronic Sow Feeding
Objective: Training gilts and sows to use electronic sow feeders

Graduate Student: Carine Vier
Grower Pen
11 to 21 wk old

Gilt Training Pen
21 to 23 wk old

Training Stage

ESF Pen
23 to 25 wk old

Post-Training Stage

2nd or 3rd heat

Sows for breeding
Pre-training Pen Set-up

Feeding area

Pre-feeding area

Post-feeding area
Young gilts are exposed to the process of going through a feeding station in order to eat.
Training Pen. Gate similar to ESF. Left entrance gate open at 45° angle.
Objective: Evaluate the feed efficiency of gilts and sows under commercial conditions and their reproductive performance.

Graduate Student: Lori Thomas

This project was supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68004-30336 from the USDA National Institute of Food and Agriculture
Procedures

• RFID Tags for Sow ID
• 296 Gilts
• 566 Sows
• ESF feed delivery
  – 4.4 lb/d
  – 5.0 lb/d
  – 6.6 lb/d
• ESF Daily Sow Body Weight
• 2 known points

Electronic Scale

Thomas et al. 2016
Scale set-up

After the going through the feeding station, females walk over a scale

Thomas et al. 2016
Example sow: Raw Data

Thomas et al. 2016
Gestating Sow Average Daily Gain

<table>
<thead>
<tr>
<th>Parity</th>
<th>4 to 15</th>
<th>15 to 30</th>
<th>31 to 60</th>
<th>61 to 90</th>
<th>91 to 112</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
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<td>1.50</td>
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<tr>
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<td>1.00</td>
<td>1.50</td>
<td>2.00</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Thomas et al. 2016
Average Daily Feed Intake

Day of Gestation

Parity 1
Parity 2
Parity 3+

Thomas et al. 2016
Percentage of Feed Intake of Total Offered

Day of Gestation

% of offered feed intake

4 to 15 15 to 30 31 to 60 61 to 90 91 to 112

Parity 1  Parity 2  Parity 3+

Thomas et al. 2016
Feed intake throughout the course of gestation, Parity 1
Feed intake throughout the course of gestation, Parity 2
Feed intake throughout the course of gestation, Parity 3+
Gestating Sow Feed Efficiency

Day of Gestation

F/G

Parity 1  Parity 2  Parity 3+

4 to 15  15 to 30  31 to 60  61 to 90  91 to 112

Thomas et al. 2016
Electronic Sow Feeding Implications

ESFs allow for numerous research opportunities modelling protein and lipid growth during gestation

Gilts, but even parity 2 and 3+ females have challenges going through the ESFs the first few days after placement

Will initial feed intake affect litter size?

Thomas et al. 2016
Overview of amino acid research from the last year

- Nursery pigs
  - Lysine
  - Valine
  - Isoleucine
  - Validation of amino acid ratios
  - Aminogut

- Late finishing pigs
  - DNA Lys response
  - Minimum crude protein required?
SID Lysine in diets for nursery pigs from 15 to 25 lb

SEM 0.022
Linear $P < 0.001$
Quadratic $P = 0.278$

Clark et al. 2016
SID Val:Lys in diets for nursery pigs from 15 to 25 lb

SEM 0.025
Linear $P < 0.001$
Quadratic $P < 0.001$

Clark et al. 2016
SID Val:Lys in diets for nursery pigs from 15 to 25 lb

SEM 0.038
Linear $P = 0.012$
Quadratic $P = 0.030$

Clark et al. 2016
SID Val:Lys in diets for nursery pigs from 15 to 25 lb

SEM 0.050
Linear $P = 0.084$
Quadratic $P = 0.036$

Clark et al. 2016
SID Ile:Lys in diets for nursery pigs from 15 to 25 lb (Exp 2)

SEM
Linear $P < 0.001$
Quadratic $P = 0.009$

Clark et al. 2016
SID Ile:Lys in diets for nursery pigs from 15 to 25 lb (Exp 2)

SEM
Linear $P < 0.001$
Quadratic $P = 0.002$

Clark et al. 2016
Validation of AA ratios for nursery pigs from 15 to 25 lb

Clark et al. 2016

SEM=0.015
Low Lys vs High Lys, $P = 0.001$

<table>
<thead>
<tr>
<th>Lys, %</th>
<th>1.35</th>
<th>1.25</th>
<th>1.25</th>
<th>1.25</th>
<th>1.35</th>
<th>1.35</th>
<th>1.35</th>
</tr>
</thead>
<tbody>
<tr>
<td>M &amp; C:Lys</td>
<td>58</td>
<td>55</td>
<td>56</td>
<td>60</td>
<td>55</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Thr:Lys</td>
<td>65</td>
<td>62</td>
<td>62</td>
<td>65</td>
<td>62</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>Trp:Lys</td>
<td>19</td>
<td>18</td>
<td>19</td>
<td>21</td>
<td>18</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Val:Lys</td>
<td>70</td>
<td>65</td>
<td>67</td>
<td>72</td>
<td>65</td>
<td>67</td>
<td>72</td>
</tr>
<tr>
<td>Ile:Lys</td>
<td>60</td>
<td>53</td>
<td>53</td>
<td>53</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

Control  | Industry | 95% of max | Maximum | Industry | 95% of max | Maximum |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.81$^{a,b}$</td>
<td>0.76$^c$</td>
<td>0.80$^{b,c}$</td>
<td>0.82$^{a,b}$</td>
<td>0.84$^a$</td>
<td>0.84$^a$</td>
<td>0.80$^b$</td>
</tr>
</tbody>
</table>

$^a,b$ SEM=0.015, $P = 0.001$
Validation of AA ratios for nursery pigs from 15 to 25 lb

Clark et al. 2016

SEM=0.015
Low Lys vs High Lys, $P = 0.001$

<table>
<thead>
<tr>
<th>AA Ratio</th>
<th>Control</th>
<th>Industry</th>
<th>95% of max</th>
<th>Maximum</th>
<th>Industry</th>
<th>95% of max</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lys, %</td>
<td>1.35</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
</tr>
<tr>
<td>M &amp; C:Lys</td>
<td>58</td>
<td>55</td>
<td>56</td>
<td>60</td>
<td>55</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Thr:Lys</td>
<td>65</td>
<td>62</td>
<td>62</td>
<td>65</td>
<td>62</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>Trp:Lys</td>
<td>19</td>
<td>18</td>
<td>19</td>
<td>21</td>
<td>18</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Val:Lys</td>
<td>70</td>
<td>65</td>
<td>67</td>
<td>72</td>
<td>65</td>
<td>67</td>
<td>72</td>
</tr>
<tr>
<td>Ile:Lys</td>
<td>60</td>
<td>53</td>
<td>53</td>
<td>53</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

Note: Values with different superscripts (a,b,c) indicate significant differences.
Validation of AA ratios for nursery pigs from 15 to 25 lb

Clark et al. 2016

SEM=0.015
Low Lys vs High Lys, P = 0.001

<table>
<thead>
<tr>
<th>AA Ratios</th>
<th>Control</th>
<th>Industry</th>
<th>95% of max</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
<td>Lys, %</td>
<td>1.35</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
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<td>55</td>
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<td>Thr:Lys</td>
<td>65</td>
<td>62</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>Trp:Lys</td>
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<td>18</td>
<td>19</td>
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<td>72</td>
</tr>
<tr>
<td>Ile:Lys</td>
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<tr>
<td>Lys, %</td>
<td>1.35</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
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<tr>
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<tr>
<td>Ile:Lys</td>
<td>60</td>
<td>53</td>
<td>53</td>
<td>53</td>
</tr>
</tbody>
</table>
Validation of AA ratios for nursery pigs from 15 to 25 lb

Clark et al. 2016

<table>
<thead>
<tr>
<th>Lys, %</th>
<th>Control</th>
<th>Industry</th>
<th>95% of max</th>
<th>Maximum</th>
<th>Industry</th>
<th>95% of max</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.35</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
</tr>
</tbody>
</table>

SEM=0.020
Low Lys vs High Lys, \( P = 0.692 \)

| M & C:Lys | 58 | 55 | 56 | 60 | 55 | 56 | 60 |
| Thr:Lys   | 65 | 62 | 62 | 65 | 62 | 62 | 65 |
| Trp:Lys   | 19 | 18 | 19 | 21 | 18 | 19 | 21 |
| Val:Lys   | 70 | 65 | 67 | 72 | 65 | 67 | 72 |
| Ile:Lys   | 60 | 53 | 53 | 53 | 52 | 52 | 52 |

Note: superscript letters indicate differences.
**Validation of AA ratios for nursery pigs from 15 to 25 lb**  
Clark et al. 2016

<table>
<thead>
<tr>
<th>F/G</th>
<th>Control</th>
<th>Industry</th>
<th>95% of max</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.22</td>
<td>1.30(^a)</td>
<td>1.29(^{a,b})</td>
<td>1.25(^{b,c,d})</td>
<td>1.22(^d)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lys, %</th>
<th>1.35</th>
<th>1.25</th>
<th>1.25</th>
<th>1.25</th>
<th>1.35</th>
<th>1.35</th>
<th>1.35</th>
</tr>
</thead>
<tbody>
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<td>M &amp; C:Lys</td>
<td>58</td>
<td>55</td>
<td>56</td>
<td>60</td>
<td>55</td>
<td>56</td>
<td>60</td>
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<tr>
<td>Thr:Lys</td>
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<td>62</td>
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<td>62</td>
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</tr>
<tr>
<td>Trp:Lys</td>
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<td>19</td>
<td>21</td>
<td>18</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Val:Lys</td>
<td>70</td>
<td>65</td>
<td>67</td>
<td>72</td>
<td>65</td>
<td>67</td>
<td>72</td>
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<tr>
<td>Ile:Lys</td>
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<td>53</td>
<td>53</td>
<td>53</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

SEM=0.0153  
Low Lys vs High Lys, \(P < 0.001\)
Summary 15 to 25 lb pigs

✓ SID Lys – 1.45 to 1.60%
✓ SID Val:Lys – 63 to 72%
✓ SID Ile:Lys – 52%
✓ Results dependent on the model and criteria
✓ Higher ratios are required when lower lysine diets are fed.
✓ Generating response surfaces allows producers and nutritionists to make decisions based on ingredient nutrient composition, availability, and economics
Effect of SID Lys levels in DNA finishing pigs from 225 to 280 lb

Linear, \( P = 0.260 \)
Quadratic, \( P = 0.015 \)
SEM = 0.059

Soto et al. 2016
Effect of SID Lys levels in DNA finishing pigs from 225 to 280 lb

<table>
<thead>
<tr>
<th>SID Lys, %</th>
<th>F/G</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.45</td>
<td>3.26</td>
</tr>
<tr>
<td>0.55</td>
<td>3.10</td>
</tr>
<tr>
<td>0.65</td>
<td>3.04</td>
</tr>
<tr>
<td>0.75</td>
<td>3.13</td>
</tr>
</tbody>
</table>

Linear, $P = 0.191$
Quadratic, $P = 0.058$
SEM = 0.007

Soto et al. 2016
Minimum dietary crude protein for finishing pigs from 240 to 280 lb

Linear, $P = 0.001$
Quadratic, $P = 0.080$
SEM = 0.068

<table>
<thead>
<tr>
<th>Crude protein, %</th>
<th>ADG, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>1.69</td>
</tr>
<tr>
<td>11.0</td>
<td>1.89</td>
</tr>
<tr>
<td>12.0</td>
<td>2.01</td>
</tr>
<tr>
<td>13.0</td>
<td>1.99</td>
</tr>
</tbody>
</table>

Soto et al. 2016
Minimum dietary crude protein for finishing pigs from 240 to 280 lb

<table>
<thead>
<tr>
<th>Crude protein, %</th>
<th>ADFI, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>5.69</td>
</tr>
<tr>
<td>11.0</td>
<td>5.99</td>
</tr>
<tr>
<td>12.0</td>
<td>6.26</td>
</tr>
<tr>
<td>13.0</td>
<td>6.09</td>
</tr>
</tbody>
</table>

Linear, $P = 0.014$

Quadratic, $P = 0.060$

SEM = 0.127

Soto et al. 2016
Minimum dietary crude protein for finishing pigs from 240 to 280 lb

<table>
<thead>
<tr>
<th>F/G</th>
<th>Crude protein, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>3.35</td>
</tr>
<tr>
<td>11.0</td>
<td>3.18</td>
</tr>
<tr>
<td>12.0</td>
<td>3.11</td>
</tr>
<tr>
<td>13.0</td>
<td>3.06</td>
</tr>
</tbody>
</table>

Linear, \( P = 0.014 \)
Quadratic, \( P = 0.060 \)
SEM = 0.127

Soto et al. 2016
Effect of electrolyte balance and crude protein in finishing pigs from 240 to 280 lb

<table>
<thead>
<tr>
<th>ADG, lb</th>
<th>dEB x CP, P = 0.236</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dEB, P = 0.442</td>
</tr>
<tr>
<td></td>
<td>CP, P = 0.001</td>
</tr>
<tr>
<td></td>
<td>SEM = 0.046</td>
</tr>
</tbody>
</table>

- 48 dEB (mg/kg) 10% CP
  - 1.58

- 107 dEB (mg/kg) 13% CP
  - 1.78

- 48 dEB (mg/kg) 13% CP
  - 1.69

- 107 dEB (mg/kg) 13% CP
  - 1.78

Soto et al. 2016
Effect of electrolyte balance and crude protein in finishing pigs from 240 to 280 lb

Comparison of F/G (Feed to Gain) with different electrolyte balance (dEB) and protein levels (CP):

- 10% CP, dEB 48 mg/kg: F/G = 3.96
- 10% CP, dEB 107 mg/kg: F/G = 3.93
- 13% CP, dEB 48 mg/kg: F/G = 3.60
- 13% CP, dEB 107 mg/kg: F/G = 3.57

Statistical analysis:
- dEB x CP, P = 0.948
- dEB, P = 0.734
- CP, P = <0.001
- SEM = 0.087

Soto et al. 2016
Late finishing amino acid summary

- 0.55 to 0.65% SID Lys required from 240 to 280 lb
- Minimum dietary crude protein of 12%
  - Electrolyte balance is not reason for poor performance of pigs fed lower CP diets in late finishing.
Mineral research
Added salt for 15–22 lb nursery pigs on ADFI (d 0 to 14)

Linear, \( P < 0.015 \)

SEM = 0.021

<table>
<thead>
<tr>
<th>Diet Na, %</th>
<th>Added Salt, lb/ton</th>
<th>ADFI, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.13</td>
<td>0</td>
<td>0.68</td>
</tr>
<tr>
<td>0.21</td>
<td>4</td>
<td>0.67</td>
</tr>
<tr>
<td>0.29</td>
<td>8</td>
<td>0.70</td>
</tr>
<tr>
<td>0.37</td>
<td>12</td>
<td>0.72</td>
</tr>
<tr>
<td>0.45</td>
<td>16</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Shawk et al., 2016

NRC, 2012

0.35% Na
Added salt for 15–22 lb nursery pigs on ADG (d 0 to 14)

Linear, $P < 0.001$
SEM = 0.023

<table>
<thead>
<tr>
<th>Added Salt, lb/ton</th>
<th>Diet Na, %</th>
<th>ADG, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.13</td>
<td>0.43</td>
</tr>
<tr>
<td>4</td>
<td>0.21</td>
<td>0.48</td>
</tr>
<tr>
<td>8</td>
<td>0.29</td>
<td>0.52</td>
</tr>
<tr>
<td>12</td>
<td>0.37</td>
<td>0.56</td>
</tr>
<tr>
<td>16</td>
<td>0.45</td>
<td>0.56</td>
</tr>
</tbody>
</table>

NRC, 2012
0.35% Na

Shawk et al., 2016
Added salt for 15–22 lb nursery pigs on F/G (d 0 to 14)

Linear, $P < 0.001$

Quadratic, $P < 0.034$

SEM = 0.048

Shawk et al., 2016

NRC, 2012

0.35% Na
Added Na and Cl for 15–24 lb nursery pigs (d 0 to 14)

\[ \text{ADG, lb} \]

\[ \begin{align*}
\text{Whey} & : 0.62^a \\
\text{Lactose} & : 0.55^b \\
\text{Lactose} & : 0.63^a \\
\text{Lactose} & : 0.60^{ab}
\end{align*} \]

\( ^a \) Means differ \( P < 0.05 \)

\( \text{SEM} = 0.021 \)

\begin{tabular}{|c|c|c|c|}
\hline
& \text{Diet Na, \%} & \text{Diet Cl, \%} & \\
\hline
\text{Whey} & 0.37 & 0.75 & \\
\text{Lactose} & 0.18 & 0.47 & \\
\text{Lactose} & 0.35 & 0.72 & \\
\text{Lactose} & 0.35 & 0.45 & \\
\hline
\end{tabular}

Shawk et al., 2016
Cu source on nursery pig ADG (13-48 lb)

Source x level, $P = 0.296$
Cu source; $P = 0.712$
Cu linear, $P = 0.048$
SEM = 0.146

Added Cu, ppm  
0  75  150  225

IntelliBond-C

Mintrex-Cu

Carpenter et al., 2016
Cu source on nursery pig F/G (13-48 lb)

Source x level, $P > 0.565$
Cu source; $P = 0.943$
Cu linear, $P = 0.091$
SEM = 0.039

Added Cu, ppm 0 75 150 225
IntelliBond-C 1.47 1.47 1.45 1.44
Mintrex-Cu 1.49 1.43 1.44

Carpenter et al., 2016
Cu source on finishing pig ADG (82-285 lb)

Cu source; $P = 0.573$

Cu level, $P > 0.249$

SEM = 0.022

ADG, lb

1.92 1.95 1.96 1.95 1.96

Added Cu, ppm

0 70 130 70 100 130

Cu Sulfate

Cu Sulfate/Availa Cu

Carpenter et al., 2016
Cu source on finishing pig F/G (82-285 lb)

Cu source; $P = 0.048$
Cu level, $P > 0.124$
SEM = 0.022

Added Cu, ppm 0 70 130 70 100 130
F/G 2.79 2.79 2.78 2.76 2.76 2.72
Cu Sulfate
Cu Sulfate/Availa Cu

Carpenter et al., 2016
Zn source on finishing pig ADG (70-280 lb)

Source x level, $P > 0.376$

Zn level; quadratic $P = 0.007$

Zn source, $P = 0.555$

$SEM = 0.020$

<table>
<thead>
<tr>
<th>Added Zn, ppm</th>
<th>Zn Sulfate</th>
<th>Intellibond-Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2.07</td>
<td>2.14</td>
</tr>
<tr>
<td>100</td>
<td>2.11</td>
<td>50</td>
</tr>
<tr>
<td>150</td>
<td>2.09</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td>2.09</td>
<td>150 Intellibond-Z</td>
</tr>
<tr>
<td>100</td>
<td>2.14</td>
<td>2.07</td>
</tr>
</tbody>
</table>

Carpenter et al., 2016
Zn source on finishing pig IOFC (constant day)

Source x level, $P > 0.143$
Zn level; quadratic $P = 0.007$
Zn source, $P = 0.125$
SEM = 1.245

Added Zn, ppm
- 50
- 100
- 150

Zn Sulfate
- 123.91
- 126.63
- 125.22

Intellibond-Z
- 126.56
- 129.53
- 124.39

Carpenter et al., 2016
Superdose Natuphos E 5,000 G on nursery pig F/G (13-49 lb)

<table>
<thead>
<tr>
<th>Added phytase, FTU/kg</th>
<th>PC vs. PC 2,000, $P = 0.068$</th>
<th>NC 500 vs. PC 0, $P = 0.034$</th>
<th>NC quadratic, $P = 0.007$</th>
<th>SEM = 0.015</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.46</td>
<td>1.40</td>
<td>1.42</td>
<td>1.42</td>
</tr>
<tr>
<td>500</td>
<td></td>
<td>1.42</td>
<td>1.42</td>
<td>1.42</td>
</tr>
<tr>
<td>1,000</td>
<td></td>
<td></td>
<td>1.42</td>
<td>1.42</td>
</tr>
<tr>
<td>2,000</td>
<td></td>
<td></td>
<td></td>
<td>1.46</td>
</tr>
<tr>
<td>3,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
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<td></td>
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<td>1.45</td>
</tr>
<tr>
<td>2,000</td>
<td></td>
<td></td>
<td></td>
<td>1.41</td>
</tr>
</tbody>
</table>

Gourley et al., 2016
Superdose Natuphos E 5,000 G on bone ash %
(13-49 lb)

PC vs. PC 2,000, $P = 0.001$
NC 500 vs. PC 0, $P = 0.009$
NC lin & quad, $P < 0.007$
SEM = 0.015

Added phytase, 0 FTU/kg

<table>
<thead>
<tr>
<th>FTU/kg</th>
<th>500</th>
<th>1,000</th>
<th>2,000</th>
<th>3,000</th>
<th>4,000</th>
<th>2,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone ash, %</td>
<td>44.2</td>
<td>45.2</td>
<td>47.1</td>
<td>48.0</td>
<td>48.4</td>
<td>49.1</td>
</tr>
</tbody>
</table>

Gourley et al., 2016
Calculated avP release from Natuphos E 5,000 G

Bone ash weight avP release = 0.000116 × FTU/kg
% bone ash avP release = avP release = 0.000212 × FTU/kg

Gourley et al., 2016
Standardized total tract digestible phosphorus ADG, 25 to 50 lb pigs

Modeling estimates:
QP and LM: Greater than 0.53%

SEM = 0.026
Linear, $P < 0.001$
Quadratic, $P = 0.718$

<table>
<thead>
<tr>
<th>STTD P, %</th>
<th>ADG, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.26</td>
<td>1.10</td>
</tr>
<tr>
<td>0.30</td>
<td>1.12</td>
</tr>
<tr>
<td>0.33</td>
<td>1.17</td>
</tr>
<tr>
<td>0.38</td>
<td>1.17</td>
</tr>
<tr>
<td>0.43</td>
<td>1.25</td>
</tr>
<tr>
<td>0.48</td>
<td>1.24</td>
</tr>
<tr>
<td>0.53</td>
<td>1.26</td>
</tr>
</tbody>
</table>

% of NRC
80 90 100 115 130 145 160

Vier et al. 2017
Standardized total tract digestible phosphorus
ADFI, 25 to 50 lb pigs

<table>
<thead>
<tr>
<th>STTD P, %</th>
<th>0.26</th>
<th>0.30</th>
<th>0.33</th>
<th>0.38</th>
<th>0.43</th>
<th>0.48</th>
<th>0.53</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of NRC</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>115</td>
<td>130</td>
<td>145</td>
<td>160</td>
</tr>
<tr>
<td>ADFI, lb</td>
<td>1.72</td>
<td>1.68</td>
<td>1.71</td>
<td>1.72</td>
<td>1.80</td>
<td>1.82</td>
<td>1.82</td>
</tr>
</tbody>
</table>

SEM = 0.043
Linear, $P < 0.004$
Quadratic, $P = 0.603$

Vier et al. 2017
Standardized total tract digestible phosphorus F/G, 25 to 50 lb pigs

SEM = 0.007
Linear, \( P < 0.001 \)
Quadratic, \( P = 0.067 \)

QP: 0.43\% (95\% CI: [0.36, > 0.53]\%)

99\% of maximum G:F achieved at 0.36%.

BLL: 0.34\% (95\% CI: [0.29, 0.38]\%)

Vier et al. 2017
Standardized total tract digestible phosphorus

ADG, d 0 to 111

SEM = 0.014
Linear, \( P < 0.001 \)
Quadratic, \( P < 0.001 \)

STTD P, % of NRC (2012)

Vier et al. 2017
Standardized total tract digestible phosphorus
ADFI, d 0 to 111

SEM = 0.051
Linear, $P < 0.032$
Quadratic, $P = 0.102$

STTD P, % of NRC (2012)

Vier et al. 2017
Standardized total tract digestible phosphorus F/G, d 0 to 111

STTD P, % of NRC (2012)

Vier et al. 2017
Effects of dietary Ca:P ratio on growth performance of nursery pigs

- Objective:
  To determine the growth performance of nursery pigs fed 2 levels of Ca in combination with 3 standardized total tract digestible (STTD) P treatments.

Wu et al., 2017
Effects of dietary Ca:STTD P ratio on growth performance of nursery pigs (d 0 to 28)

Ca × P: $P < 0.01$
Ca: $P < 0.01$
P: $P < 0.01$
SEM = 0.015

NRC, 2012:
STTD P = 0.40%
Total Ca = 0.80%

ADG, lb

| Analyzed Ca | 0.58 | 1.03 | 0.58 | 1.03 | 0.46 | 0.91 |
| Ca with phytase | - | - | - | - | 0.58 | 1.03 |
| STTD P no phytase | 0.45 | 0.45 | 0.33 | 0.33 | 0.33 | 0.33 |
| STTD P w/phytase | - | - | - | - | 0.45 | 0.45 |
| Total Ca:STTD P | 1.29 | 2.29 | 1.76 | 3.12 | 1.29 | 2.29 |
Effects of dietary Ca:STTD P ratio on growth performance of nursery pigs (d 0 to 28)

<table>
<thead>
<tr>
<th>Analyzed Ca</th>
<th>0.58</th>
<th>1.03</th>
<th>0.58</th>
<th>1.03</th>
<th>0.46</th>
<th>0.91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca with phytase</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.58</td>
<td>1.03</td>
</tr>
<tr>
<td>STTD P no phytase</td>
<td>0.45</td>
<td>0.45</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>STTD P w/phytase</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Total Ca:STTD P</td>
<td>1.29</td>
<td>2.29</td>
<td>1.76</td>
<td>3.12</td>
<td>1.29</td>
<td>2.29</td>
</tr>
</tbody>
</table>

NRC, 2012:
- STTD P = 0.40%
- Total Ca = 0.80%

SEM = 0.013
Mycotoxins reported in 2016 corn

**Fumonisin**
- Kansas, North Carolina, Missouri, Texas, Illinois, Oklahoma

**Deoxynivalenol (Vomitoxin or DON)**
- Ohio, Michigan, Illinois, Indiana, Iowa, Ontario, Canada

**Aflatoxin**
- Kansas, Oklahoma, Louisiana, Alabama, South Carolina, North Carolina, Georgia, Texas

**Zearalenone**
- Iowa
Management
TEAM!!!
Blending Left Over Finishing Feed

• Left-over finishing feed in wean-to-finish production creates challenge in feed management
  – Due to imperfect feed budgeting
  – Issues with storage capacity, tandem contamination

• Reclaim vs. blend in nursery diets in the next turn
  – When to blend?
  – Effects on growth performance and economics?

Wu et al., 2016
# Feed budget

<table>
<thead>
<tr>
<th>Phase</th>
<th>Control</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>5.47 lb</td>
<td>5.47 lb</td>
<td>5.47 lb</td>
<td>5.47 lb</td>
</tr>
<tr>
<td>Phase 2</td>
<td>8.07 lb</td>
<td>2.75 lb finishing feed,</td>
<td>8.07 lb</td>
<td>8.07 lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5 lb 50:50% blend,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5 lb standard Phase 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 3</td>
<td>8.07 lb</td>
<td>8.07 lb</td>
<td>2.75 lb finishing feed,</td>
<td>8.07 lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.5 lb 50:50% blend,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.5 lb standard Phase 3</td>
<td></td>
</tr>
<tr>
<td>Phase 4</td>
<td>21 lb</td>
<td>21 lb</td>
<td>21 lb</td>
<td>2.75 lb finishing feed,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.5 lb 50:50% blend,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.5 lb standard Phase 4</td>
</tr>
<tr>
<td>Phase 5</td>
<td>21 lb</td>
<td>15.5 lb</td>
<td>15.5 lb</td>
<td>15.5 lb</td>
</tr>
</tbody>
</table>
Overall growth performance

ADG: $P < 0.05$
ADFI: $P < 0.05$
F/G: $P = 0.14$

ADG, lb
- Control
- Phase 2 blending
- Phase 3 blending
- Phase 4 blending

ADF, lb

FG

Wu et al., 2016

a, b Least squares means differ ($P \leq 0.05$)
Reclaiming feed ($290 per group @ $0.23/head) is more cost effective than feeding in any phase of the nursery!

**Economics**

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economics, $/pig</td>
<td>12.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.134</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Feed cost</td>
<td>0.232</td>
<td>0.231</td>
<td>0.230</td>
<td>0.234</td>
<td>0.0020</td>
<td>0.410</td>
</tr>
<tr>
<td>Gain value</td>
<td>31.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.64&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31.18&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>31.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.334</td>
<td>0.031</td>
</tr>
<tr>
<td>Feed cost/lb gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IOFC</td>
<td>19.58</td>
<td>18.89</td>
<td>19.16</td>
<td>19.26</td>
<td>0.261</td>
<td>0.317</td>
</tr>
<tr>
<td>Breakeven cost for reclaiming feed, $</td>
<td>-</td>
<td>1,518</td>
<td>924</td>
<td>704</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Wu et al., 2016
Effects of Pig Space Allowance on Finishing Pig Growth Performance

C.J. Holder

Undergraduate Research Symposium

May 6th, 2106


ADG, d 0 to 71

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ADG, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.8 Ft²</td>
<td>2.21</td>
</tr>
<tr>
<td>6.3 Ft²</td>
<td>2.04</td>
</tr>
<tr>
<td>Gate</td>
<td>2.14</td>
</tr>
<tr>
<td>Removal</td>
<td>2.15</td>
</tr>
</tbody>
</table>

Holder et al. 2016
Discussion

• Space restriction began to influence growth rate between 153 and 182 lb.

• Confirms research by Thomas et al., 2015 and Flohr et al. (2015) which suggests reductions in growth due to occur prior to when the pigs reach the critical $k$ value.
Floor space Tool

Josh Flohr Meta analysis 2015
# Floor space calculator

<table>
<thead>
<tr>
<th>Adjustment observation</th>
<th>Input information required (Can do five estimates)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Initial BW, lbs</td>
<td>50</td>
</tr>
<tr>
<td>Final BW, lbs</td>
<td>280</td>
</tr>
<tr>
<td>Stocking density, pigs/pen</td>
<td>26</td>
</tr>
<tr>
<td>Floor space/pig, ft²</td>
<td>6.9</td>
</tr>
<tr>
<td>Observed ADG, lb</td>
<td>1.87</td>
</tr>
<tr>
<td>Observed ADFI, lb</td>
<td>5.7</td>
</tr>
<tr>
<td>Pen width, ft</td>
<td>10</td>
</tr>
<tr>
<td>Pen length, ft</td>
<td>18</td>
</tr>
<tr>
<td>k value</td>
<td>0.0250</td>
</tr>
</tbody>
</table>

**Growth measurement estimates**

| ADG, lb/d      | 1.63 | 1.63 | 1.68 | 1.74 | 1.80 |
| ADFI, lb/d     | 6.01 | 6.01 | 6.12 | 6.24 | 6.37 |
| G:F            | 0.272| 0.272| 0.275| 0.279| 0.283|
| Feed/gain      | 3.68 | **3.68** | 3.63 | 3.58 | 3.54 |

*Josh Flohr Meta analysis 2015*
A review of heavy weight market pigs: status of knowledge and future needs assessment


Acknowledgement:
Funding for this review was provided by: National Pork Board

Wu et al., 2017 Translational Animal Science
Summary

• Marketing weight will continue increase
  – 0.5 kg/yr (1.2 lb/yr; NASS, 2014)

• Genetic selection of lean genotype is the driving force for increasing marketing weight

• Limited information is available concerning nutritional requirements of pigs > 140 kg (310 lb)

• Facility design and packing plant equipment need to be adjusted for biological and physical requirements of heavy pig

Wu et al., 2017 Translational Animal Science
Swine production around the world is differentiating based on health and productivity.
VFD Management

- Biosecurity
- Increase Wean Age
- Pathogen Elimination
  - Eradicate mycoplasma
  - Control pathogen spread in the growing pig
Antibiotics in Livestock Production

Antibiotic resistance
- KSU Factsheets
- Overview
- Mechanisms
- Livestock production
- USDA and FDA action plans
- News Feeds

Regulations and veterinary feed directives

Alternatives to antibiotics in livestock production

Management practices to reduce the need for antibiotics

This work is/was supported by the USDA National Institute of Food and Agriculture, AFRI Food Safety Challenge Grant project 2013-68003-21257. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA or NIFA.
Evaluating the Effects of Replacing Feed Grade Antibiotics with Yeast, Essential Oils or Zinc Oxide and Copper Sulfate on Nursery Pig Performance

Jim L. Nelssen, Austin Langemeier, Spencer Scotten and Morgan Cox
Comparison of Corn Yield in Iowa vs. Italy, 1994-2015

Source: USDA-FOASTAT and Eurostat
Introduction

• Since feed-grade antibiotics became available to the swine industry in the mid-1950s, research has shown that dietary inclusions of these antimicrobial agents improve growth rate and feed efficiency of nursery pigs.

• Veterinarian Feed Directive will eliminate the use of growth promoting antibiotics in swine feeds
Purpose

• Many swine producers have shared their concern with possible production losses caused by the elimination of antimicrobial agents use in swine diets, in particularly the nursery phase.

Two critical points

• Major retailers and meat producers are taking a clear stance – CONSUMER DRIVEN.

• Several classes of feed additives have been suggested as possible replacements
Objective

• The objective of this experiment was to compare the growth performance of nursery pigs fed diets containing carbadox and different dietary supplements that are commonly fed as antibiotic alternatives
  1. Pharmacological levels of Zn and Cu
  2. Essential oils (cinnamon)
  3. Yeast (cells and cell walls)

• Fed alone or in combination
Procedures

• 288 pigs (DNA 200 × 400); 11.8 lb BW

• 42-d study, with 4 pigs per pen and 8 replications per treatment

• Includes 9 dietary treatments

• Phase I -- d 0-7
• Phase II -- d 7-28
• Phase III d -- 28-42
<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>Corn</td>
<td>37.35</td>
<td>36.35</td>
<td>37.25</td>
<td>36.90</td>
<td>37.30</td>
<td>36.80</td>
<td>36.85</td>
<td>37.20</td>
<td>36.75</td>
<td></td>
</tr>
<tr>
<td>Blood meal</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
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</tr>
<tr>
<td>Blood plasma</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
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<tr>
<td>Corn DDGS</td>
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<td>5.00</td>
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<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
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</tr>
<tr>
<td>Fish meal</td>
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<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Milk, whey powder</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Choice White Grease</td>
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<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
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</tr>
<tr>
<td>Vitamins, Min., and AA</td>
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<td>3.11</td>
<td>3.11</td>
<td>3.11</td>
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<td>3.11</td>
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<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
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<tr>
<td>Mecadox</td>
<td>---</td>
<td>1.00</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Yeast</td>
<td>---</td>
<td>---</td>
<td>0.11</td>
<td>---</td>
<td>---</td>
<td>0.11</td>
<td>---</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<tr>
<td>XTRACT 6930</td>
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<td>---</td>
<td>---</td>
<td>0.05</td>
<td>---</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Copper sulfate</td>
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<td>---</td>
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<td>---</td>
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</tr>
<tr>
<td>Zinc Oxide</td>
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<td>0.42</td>
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<td>0.42</td>
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</tr>
</tbody>
</table>
### Diets Phase 2, d 7-28

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tbody>
<tr>
<td>Corn</td>
<td>54.71</td>
<td>53.71</td>
<td>54.61</td>
<td>54.38</td>
<td>54.66</td>
<td>54.28</td>
<td>54.33</td>
<td>54.56</td>
<td>54.23</td>
</tr>
<tr>
<td>Blood meal</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
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<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Fish meal</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Milk, whey powder</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Mecadox</td>
<td>---</td>
<td>1.00</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>Yeast</td>
<td>---</td>
<td>---</td>
<td>0.11</td>
<td>---</td>
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<td>---</td>
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<tr>
<td>XTRACT 6930</td>
<td>---</td>
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<td>---</td>
<td>---</td>
<td>0.05</td>
<td>---</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
<td>Copper sulfate</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.05</td>
<td>---</td>
<td>0.05</td>
<td>0.05</td>
<td>---</td>
<td>0.05</td>
</tr>
<tr>
<td>Zinc Oxide</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.28</td>
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<td>0.28</td>
<td>0.28</td>
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<td>0.28</td>
</tr>
</tbody>
</table>
Different superscripts denote ($P < 0.05$)
Different superscripts denote ($P < 0.05$)
ADG d 7-28

Different superscripts denote ($P < 0.05$)

Control: 0.7\textsuperscript{a}

Carbadox: 0.81\textsuperscript{b}

Copper + Zinc: 0.84\textsuperscript{b}
Days 7-28 ADFI

Different superscripts denote ($P < 0.05$)

- Control: $1.26^a$
- Carbadox: $1.40^b$
- Copper + Zinc: $1.43^b$
Days 7-28 F/G

Control: 1.79<sup>a</sup>  
Carbadox: 1.73<sup>b</sup>  
Copper + Zinc: 1.70<sup>b</sup>

Different superscripts denote ($P < 0.05$)
Day 42 Body Weight

Different superscripts denote ($P < 0.05$)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>44.3 a</td>
</tr>
<tr>
<td>Carbadox</td>
<td>47.1 b</td>
</tr>
<tr>
<td>Copper + Zinc</td>
<td>49.4 b</td>
</tr>
</tbody>
</table>
Results

• During Phase 1 & 2 (d 0 to 28)
  – Pigs fed carbadox proved to have increased ADG ($P < 0.05$) compared to pigs fed a non-medicated control diet.
  – Pigs fed pharmacological trace minerals (Cu + Zn) had equal ($P > 0.05$) growth performance with those fed carbadox.
  – Pigs fed pharmacological levels of Zn and Cu outperformed control pigs during this period.
Discussion

- We fed carbadox to nursery pigs and found a consistent improvement in growth performance compared to pigs fed a non-medicated diet.

- In addition, pigs fed the zinc oxide and copper sulfate combination were over 5 pounds heavier ($P < 0.0081$) at the end of the nursery phase (d-42) compared to pigs fed an antibiotic free control diet.
Economics

• Ingredient cost per ton, Phase 1
  – Control: $662.28/ton
  – Carbadox: $687.89/ton
  – Copper + Zinc: $669.83/ton

• Copper + Zinc Diet is $18.06 cheaper per ton when compared to carbadox
Economics

• Ingredient cost per ton, Phase 2
  – Control: $348.80/ton
  – Carbadox: $374.41/ton
  – Copper + Zinc: $354.06/ton

• Copper + Zinc Diet is $20.35 cheaper per ton when compared to carbadox
Dietary Essential Oils and Acidification Effects of Growing Pig Death Loss

Growing Pig (0 to 28 Day-Trial)

Control: 7%  
P < .07

Acidification and Essential Oils: 1%

1 VevoWin provided by DSM
THANKS to all our sponsors for their support of the 2016 KSU Swine Day