Establishing Optimum Gut Health In Young Pigs – Key Challenges And Considerations

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About Danisco Animal Nutrition

Danisco Animal Nutrition (animalnutrition.dupont.com), a business division of DuPont Industrial Biosciences, helps animal producers around the world maximize the return on their feed investment, improve liveability and tackle commercial sustainability challenges.

The company achieves this by collaborating with them to deliver optimized enzyme, betaine and probiotic feed solutions. Its uniqueness centres on the way it combines these technologies - many of which are industry "firsts" - to form solutions that deliver superior customer value. Its ability to shape a profitable and sustainable future for animal producers is underpinned by the quality and quantity of its worldwide trials, its unparalleled investment in innovative technologies and its collaboration with leading international industry, government and academic partners.

The company is also part of DuPont (www.dupont.com), which has become one of the most innovative and admired biotechnology organizations in the world.
Today’s Speakers

Dr. John Pluske
Australian-American Fulbright Commission
Distinguished Chair in Agriculture and Life Sciences
at Kansas State University and Professor at Murdoch University in Perth, Western Australia

Dr. Gary Partridge
Global Development and Technical Director,
Danisco Animal Nutrition
Dr. John Pluske is currently the Australian-American Fulbright Commission Distinguished Chair in Agriculture and Life Sciences at Kansas State University, and a Professor at Murdoch University in Perth, Western Australia. He gained his qualifications at the University of Western Australia, graduating first with a Bachelor of Science (Agriculture) degree and then a PhD. He has since carried out post-doctoral studies on pig nutrition and health at the Department of Animal Science at the University of Alberta, Edmonton, Canada and the School of Veterinary Studies at Murdoch University, Western Australia. John returned to Murdoch University in Perth in 1999 and has since worked in several senior roles in the School of Veterinary and Biomedical Sciences before assuming his current position. His current research is focussed on swine nutrition and the digestive physiology of pigs, particularly piglets and weanling pigs, and also swine immune function and controlling enteric diseases in pigs without antimicrobials.
Gut Health In Young Pigs – Perspectives And Considerations

DR JOHN PLUSKE

FULBRIGHT DISTINGUISHED CHAIR, KANSAS STATE UNIVERSITY; MURDOCH UNIVERSITY, WESTERN AUSTRALIA
What I Will Cover Today

- What is gut health?
- Relevance of gut health to the weaned pig
- Two key considerations,
  - Gut barrier function
  - The gut microbiota
What Is Gut Health?

Gut health is a term that lacks a clear and concise definition, despite its repeated use in both animal and human health, medicine and nutrition. The best definition is by Bischoff, 2011 in *Gut health*: a new objective in medicine? *(BMC Medicine 9:24)*:

- Effective digestion and absorption of feed
- Absence of gastrointestinal tract illness
- Normal and stable microbiome of the gastrointestinal tract
- Effective immune status
- Status of animal ‘well-being’
What Influences Gut Health?

Nutrition

Immune function

Homeostasis/Homeorhesis

Environment

Management

Genotype

Behaviour/Welfare

Microbiome
In pig production, it is *mostly* used in association with feed ingredients (nutrients)/additives and (or) feeding strategies, in relation to:

- The post-weaning period, and concomitantly with,
- ‘Antibiotic growth promoters’ (AGPs), ‘antibiotic resistance’, ‘antibiotic bans’ etc.

For example: “**XXXXX is considered a good candidate for substitution of AGPs in diets, due to their potential positive influence on microbial activity and health of the host**”

[Term should be used more generally to refer to any phase of the production cycle where an insult to the gastrointestinal tract occurs]
Antibiotic Uses In The Livestock Industries

- **Therapeutic use**
  - Treat clinically diseased animals

- **Prophylactic use**
  - Prevent and control common disease events

- **Sub-therapeutic use**
  - Weight gain
  - Feed efficiency
  - *Antibiotic growth promoters* (AGPs)
Changes in the use of antimicrobials and the effects on productivity of swine farms in Denmark

(Aarestrup et al., 2010; Am. J. Vet. Res. 71:726–733)

Treatment, promotion, commotion: antibiotic alternatives in food-producing animals

(Allen et al., 2013; Trends Microbiol. 21:114-119)
Study In Denmark Shows No Negative Impact On Swine Productivity When Antimicrobial Use Is Reduced

From 1992-1998, a >50% reduction in anti-microbial consumption per kg of pig produced was observed in Denmark...During the same period, overall swine productivity improved markedly, which suggests that the change in antimicrobial consumption has not had a negative impact on long term swine productivity.

Table shows AGP consumption in black, therapeutic consumption in grey. AGP bans for finishers in 1998, weaners 2000

Weaners<35kg
Finishers >35kg

Taken from “Changes in the use of antimicrobials and the effects on productivity of swine farms in Denmark” Aarestrup et al., 2010; Am. J. Vet. Res. 71:726–733)
Use Of High Levels Of Zn And Cu, Often Considered ‘Alternatives’ To AGPs, May Have Unintended Consequences

Prevalence of methicillin resistant *Staphylococcus aureus* (MRSA) from birth to 4-weeks post-weaning (exposure to starter ration containing ZnO began just after sampling on d 21)

(Slifierz *et al.*, 2014; In *33rd Centralia Swine Research Update*, Kirkton, ON; 2014)

Effects of pig manure containing copper and zinc on microbial community assessed via phospholipids in soils
Weaning: A Critical Production Step That Impacts Gastrointestinal Tract ‘Health

- Weaning imposes **multiple** and **simultaneous** stressors on young pigs,
  - Nutritional,
  - Psychological,
  - Environmental

- Post-weaning “growth check”. Aim after weaning is to **reduce** the **negative** impact weaning has on production, disease, morbidity and mortality
Sub-optimal Feed Intake After Weaning Compromises Gut Barrier Function

- Period of temporary **starvation** after weaning compromises gut barrier function.

- Low feed intake:
  - Increases numbers of lymphocytes and infiltrated cells in epithelium.
  - Causes a transient inflammatory response (up-regulation of e.g., IL-1β, IL-6, TNF-α).
  - Decreases epithelial tissue resistance (more “leaky” intestines).
Pigs Eating More Food After Weaning Have Higher Villi In The Small Intestine

Barrier Function Is Compromised In Pigs Weaned At 19 Days Of Age

High TER; intact epithelial barrier
Low TER; more permeable epithelial barrier

M-S, $^3$H-mannitol flux
High Flux Rate; more permeable epithelial barrier
Low Flux Rate; intact epithelial barrier

(from Moeser et al., 2007; Am. J. Physiol. 292:G173-181)
Weaning-induced Stress Causes Intestinal Epithelial Barrier Dysfunction

(from Moeser et al., 2007; Am. J. Physiol. 292:G173-181)
Major Factors Influencing Barrier Function After Weaning - a summary

Thickness of arrows indicate biological significance of the relationship

(from Wijtten et al., 2011; Br. J. Nutr., 105:97–981)
The Pig Gut Microbiota – Many Searching For Answers!

Number of publications and citations per paper (1995-2014) for the words “pig gut microbiota”

(Web of Science™; accessed 19th September, 2014)
Weaning: Influences On The Gut Microbiota

The number, composition and diversity of the gut microbiota after weaning is influenced by myriad of interacting factors, e.g., nutrition (AGPs, different feed additives, ingredients etc.), digestibility, environment (indoor, outdoor), disease (clinical, sub-clinical), stress.
Commensal Microbiota Prevent Colonization By Exogenous Pathogens and Pathobionts

(from Kamada et al., 2013; Nat. Immunol. 14:685-690)
Phylum-level Distribution Of The Microbiota Along The Gastrointestinal Tract Of The Growing Pig

(Looft et al., 2014; The ISME J; doi:10.1038/ismej.2014.12)
Weaning: Influences On The Gut Microbiota

- The number, composition and diversity of the gut microbiota after weaning is influenced by myriad of interacting factors, e.g., nutrition (AGPs, different feed additives, ingredients etc.), digestibility, environment (indoor, outdoor), disease (clinical, sub-clinical), stress

- Do changes in the microbiota (diversity, richness community structures) relate to changes in production indices and (or) disease-related measurements, e.g., scouring after weaning?
Results

3.1. Clinical and Production Parameters. No clinical signs and no diarrhoea episodes were observed in any animal during the whole experimental period. There were no significant differences in growth performance ($P > 0.05$).

http://dx.doi.org/10.1155/2014/269402
Dietary Plant Extracts Alleviate Diarrhea And Alter Immune Responses Of Weaned Pigs Experimentally Infected With A Pathogenic Escherichia Coli.

<table>
<thead>
<tr>
<th>Item</th>
<th>CON</th>
<th>CAP</th>
<th>GAR</th>
<th>TUR</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrhea score^5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d 0 to 2</td>
<td>1.93</td>
<td>1.67</td>
<td>1.35</td>
<td>1.36</td>
<td>0.36</td>
</tr>
<tr>
<td>d 3 to 5</td>
<td>3.43^a</td>
<td>2.50^b</td>
<td>2.13^b</td>
<td>2.00^b</td>
<td>0.31</td>
</tr>
<tr>
<td>d 6 to 8</td>
<td>2.86</td>
<td>2.58</td>
<td>2.83</td>
<td>2.90</td>
<td>0.52</td>
</tr>
<tr>
<td>d 9 to 11</td>
<td>3.51^a</td>
<td>2.13^b</td>
<td>1.21^c</td>
<td>1.15^c</td>
<td>0.26</td>
</tr>
<tr>
<td>Pig days^6</td>
<td>53</td>
<td>64</td>
<td>64</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Frequency^7</td>
<td>40</td>
<td>26</td>
<td>17</td>
<td>16</td>
<td>—</td>
</tr>
</tbody>
</table>

CON = control diet, CAP = control diet plus 10 g capsicum oleoresin/t, GAR = control diet plus 10 g garlic botanical/t, and TUR = control diet plus 10 g turmeric oleoresin/t.

(No effects of plant extracts on production measurements d 0-11 after weaning)

How Much Do We Really Know About The Gastro-intestinal Tract Microbiota?

The ultimate aim of (microbial) ecology is to understand the relationships of all organisms to their environment (Hungate (1960):

- Three principle questions:
  - What comprises the normal microbiota?
  - Where are they located?
  - What are they doing?
Further Research: The Gut Microbiota

- Establishing associations, in a dynamic manner, between changes in the microbiome (e.g., due to diet, environment, stress etc.) and production,
  - Are changes in bacterial populations the cause, or the effect, of any production changes?
  - If the cause, then how can the change(s) be exploited commercially?

- Establishing associations, in a dynamic manner, between changes in the microbiome (e.g., due to diet, environment, stress etc.) and outliers in the production system,
  - Fall-back pigs

- Establishment of the ‘appropriate’ microbiota in the young (pre-weaned) pig,
  - Influence of the dam (and perhaps the boar?) in shaping the microbiome pattern in the host
  - Manipulation of the host

- Inconsistency of effects of feed/water additives purported to improve gut health,
  - Mechanisms of action
  - Conditions under which positive effects are observed?
Differences in weights of turkeys (*Light Turkey Syndrome*) are associated with changes in the microbiome. (Succession of the turkey gastrointestinal bacterial microbiome related to weight gain, Danzeisen et al., 2013; PeerJ 1:e237; DOI 10.7717/peerj.237)
The *Ideal* Gastrointestinal Tract For The Weaned Pig (Any Pig?) Should:

- Maximize digestive and absorptive function
- Maintain appropriate balance of microbiota to minimize overgrowth and reduce risk of dysbiosis,
  - Limit increase in number of potentially pathogenic bacteria throughout the gut
  - Minimize diarrhea (microbial, secretory)
- Appropriate immune system (equilibrium; regulation *versus* inflammation)
- Minimize inflammatory insults/support antioxidant activity (e.g., under stress)
- Maintain/restore barrier function (if perturbed)
- Allow for optimum technical performance
## Growth Rate Immediately After Weaning Impacts On Lifetime Performance

<table>
<thead>
<tr>
<th>Weight (kg) on day after weaning:</th>
<th>Day 28</th>
<th>Day 56</th>
<th>Day 156 (market)</th>
<th>Days to market</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 0</td>
<td>14.7</td>
<td>30.1</td>
<td>105.4</td>
<td>183.3</td>
</tr>
<tr>
<td>0-150</td>
<td>16.0</td>
<td>31.9</td>
<td>108.2</td>
<td>179.2</td>
</tr>
<tr>
<td>150-227</td>
<td>16.9</td>
<td>32.5</td>
<td>111.3</td>
<td>175.2</td>
</tr>
<tr>
<td>≥ 227</td>
<td>18.2</td>
<td>34.8</td>
<td>113.4</td>
<td>175.3</td>
</tr>
</tbody>
</table>

[Pigs weaned at average age of 21 d and 6.23 kg. Data for d 28 and d 56 from 1,350 pigs; data for d 156 from 566 pigs]

(from Tokach et al., Swine Day 1992, Kansas State University; pp. 19-21)
Gary Partridge joined Danisco Animal Nutrition, which is today part of DuPont Industrial Biosciences, in 1994 and is now the company’s Global Development and Technical Director, specializing in swine. Before joining Danisco Animal Nutrition, he worked as a senior researcher at the Rowett Institute in Aberdeen, Scotland and then as a technical swine specialist in a premix company in the UK that later became a part of Nutreco. Gary has penned numerous scientific peer-reviewed papers and abstracts over the years, as well as many trade press articles. A member of the British Society of Animal Science and the Nutrition Society, he is co-editor of the textbook “Enzymes in Farm Animal Nutrition”.
Effects Of Anti-nutrients On Digestion In The Young Pig, And Feed Additives Relevant To Gut Integrity And Health

DR GARY PARTRIDGE
GLOBAL DEVELOPMENT AND TECHNICAL DIRECTOR
DANISCO ANIMAL NUTRITION
Some Targets To Support Optimal Growth In The Young Pig After Weaning

- **Maximize feed intake and diet digestibility**, without compromising gut health
- **Minimize costly endogenous losses** that increase maintenance energy and protein/amino acid requirements
- **Stimulate digestive function**
- ‘**Feed the gut**’ to maintain gut integrity and absorptive function
- **Stabilize the gut microbiota** to minimize risk of proliferation of non-beneficial bacteria
- **Support the developing immune system** of the young pig
The Long-term Benefits Of Improved Growth Rate In Young Pigs After Weaning Are Well Proven

<table>
<thead>
<tr>
<th>Reference</th>
<th>Each kg of extra growth after weaning*, reduced days to slaughter by :</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokach et al (1992)</td>
<td>3.0 days</td>
</tr>
<tr>
<td>Mahan et al (1998)</td>
<td>8.3 days</td>
</tr>
<tr>
<td>Pluske et al (1999)</td>
<td>3.6 days</td>
</tr>
<tr>
<td>Kim et al (2001)</td>
<td>2.3 days</td>
</tr>
<tr>
<td>Ilsley et al (2003)</td>
<td>4.3 days</td>
</tr>
</tbody>
</table>

On average, each extra kg of growth after weaning reduced days to slaughter by 4 – 5 days, worth ~€1.80 per pig at today’s prices

* Nutritional treatments after weaning varied from 1 to 3 weeks duration
The Gut – A **Major** Metabolic Organ

Gut is 5-7% of body mass but accounts for:

- 20-35% of whole body energy expenditure
- 20-60% utilization of dietary amino acids
- 100% utilization of glutamate

*Ball (2014)*
Effect Of AGP Removal In Denmark On Weaner Pig Performance (WHO 2003)

<table>
<thead>
<tr>
<th>Year</th>
<th>Age at 30kg (days)</th>
<th>Mortality %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>82.6</td>
<td>2.7</td>
</tr>
<tr>
<td>1996</td>
<td>82.6</td>
<td>2.8</td>
</tr>
<tr>
<td>1997</td>
<td>82.8</td>
<td>2.9</td>
</tr>
<tr>
<td>1998</td>
<td>82.9</td>
<td>2.9</td>
</tr>
<tr>
<td>1999</td>
<td>85.3</td>
<td>3.6</td>
</tr>
<tr>
<td>2000</td>
<td>85.5</td>
<td>3.5</td>
</tr>
<tr>
<td>2001</td>
<td>85.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

- With AGP
- Reduced AGP
- No AGP

+2.8 days
+0.7%
Feed additives that can be relevant to improving performance after weaning?

- Probiotics = DFMs e.g. live, spore-formers, ‘ghost’
- Anti-microbial peptides
- Bacteriophages
- Herbs and spices
- Essential oils
- Antibiotics e.g. zinc oxide
- Nucleotides
- Symbiotics
- Osmolytes e.g. natural betaine
- Prebiotics
- Additives e.g. inulin, lactulose
- Feed enzymes
- Carbohydrases e.g. xylanase
- Amylases
- Proteases
- Organic acids e.g. sodium butyrate, lactic
- Raw materials e.g. plasma proteins, bovine colostrum, whey, lactose
- Yeast beta-glucans
- ASF
- In situ production e.g. XOS
- Organic acids e.g. natural betaine
- Herbs and spices
- Essential oils
- Antibiotics e.g. zinc oxide
Feed additives that can be relevant to improving performance after weaning?

**Probiotics** = DFMs  
*e.g.* live, spore-formers, ‘ghost’

**Anti-microbial peptides**

**Bacteriophages**

**Herbs and spices**

**Essential oils**

**Antibiotics**  
*e.g.* zinc oxide

**Prebiotics**

*In situ production*  
*e.g.* XOS

**Feed enzymes**

**Carbohydrases**  
*e.g.* xylanase

**Amylases**

**Proteases**

**Osmolytes**  
*e.g.* natural betaine

**Nucleotides**

**Symbiotics**

**Feed enzymes**

**Organic acids**  
*e.g.* sodium butyrate, lactic

**Raw materials**  
*e.g.* plasma proteins, bovine colostrum, whey, lactose

**Yeast beta-glucans**

**Antibiotics**

**ASF**
Negating the effects of dietary anti-nutrients in the young pig

FEED ENZYMES
Arabinoxylan Content And Solubility* (%) 

- Corn: 3.9% 
- Wheat: 6.0% 
- Barley: 7.4% 
- Corn DDGS: 12.7% (10% soluble) 
- Wheat middlings: 16.5% (10% soluble) 
- Soybean meal: 3.8% 
- Canola meal: 6.5% 

*As fed basis

Source: Danisco Animal Nutrition Non Starch Polysaccharide (NSP) database
Water Holding Capacity Of The Feed And Its Effects On Feed Intake

Kyriazakis and Emmans (1995), 12-36kg pigs
Wheat Variety Can Influence Pig Growth And Feed Intake - Australia

31% variation in daily gain between the best and next-to-worst Australian wheat samples

**Table:**

<table>
<thead>
<tr>
<th>Wheat variety</th>
<th>Daily gain (g)</th>
<th>Feed intake (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>271</td>
<td>341</td>
</tr>
<tr>
<td>2</td>
<td>376</td>
<td>388</td>
</tr>
<tr>
<td>3</td>
<td>432</td>
<td>433</td>
</tr>
<tr>
<td>4</td>
<td>476</td>
<td>438</td>
</tr>
<tr>
<td>5</td>
<td>396</td>
<td>399</td>
</tr>
<tr>
<td>6</td>
<td>445</td>
<td>419</td>
</tr>
<tr>
<td>7</td>
<td>486</td>
<td>438</td>
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<tr>
<td>8</td>
<td>502</td>
<td>394</td>
</tr>
<tr>
<td>9</td>
<td>432</td>
<td>432</td>
</tr>
<tr>
<td>10</td>
<td>514</td>
<td>447</td>
</tr>
</tbody>
</table>

**Source:** Cadogan et al (1999)

Growth: P<0.001  Feed intake: P <0.001  Feed:gain: NS

65% wheat in diets
Weight 7-16 kg
Xylanase reduces variation in performance between different varieties of wheat.

**Daily gain (g)**

- Wheat variety 1: 230, 425, 460
- Wheat variety 5: 466, 445, 479
- Wheat variety 10: 318, 540, 525

FCR: 1.38, 1.27, 1.14, 1.19, 1.17, 1.19

**Feed intake (g/day)**

- Wheat variety 1: 556, 521, 570
- Wheat variety 5: 540, 525
- Wheat variety 10: 525

Improvement with xylanase:
- 103% 5% 4% 75% -4% 9%

Xylanase effects:
- Daily gain P<0.001
- Feed intake P<0.001
- FCR NS
- Wheat x Xylanase P <0.001

*Source: Choct et al (1999)*
Incidence Of Swine Dysentery & Non Starch Polysaccharide Concentration

Soluble NSP concentration (g/100 g DM)

Total NSP concentration (g/100 g DM)

Incidence Of Swine Dysentery And Resistant Starch Concentration

*In vitro estimation, after simulated digestion

Faecal Dry Matter (%) On Wheat-based Diets On A Unit Suffering From Non-specific Colitis, UK – Effect Of Xylanase

Day 1  Day 5  Day 8  Day 11  Day 15
Mash  Pellet  Pellet + Xylanase

Hazzledine and Partridge (1996)
Use Of Xylanase-supplemented Diets On A Pig Unit With A High Incidence Of *Salmonella*

Diets and feeding regime:

- *Ad libitum*
- Pelleted diets (81-85°C) with fine ground wheat (2.5mm screen) -/+ xylanase*
- Mash diets with coarse ground wheat (4mm screen) -/+ xylanase*

Blood sampling:

- Blood samples from 6 pigs per pen at random
- Blood samples analysed for *Salmonella* antibody titre by the ‘Danish Mix ELISA test’
- *Salmonella* positive = optical density value >20

* 4000 U/kg feed

The National Committee for Pig Production (Danish Bacon and Meat Council)
Both Xylanase Addition And Mash Feeding Reduced The Relative Risk Of A Pig Being *Salmonella* Positive

The National Committee for Pig Production (Danish Bacon and Meat Council)

## Variability In Xylanase Response In Grower-finisher Pigs

<table>
<thead>
<tr>
<th>Trial Report #</th>
<th>Pellets (P) or Mash (M)</th>
<th>Xylanase (X) product no.</th>
<th>Production Value Index$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>403</td>
<td>P</td>
<td>X 1</td>
<td>107*</td>
</tr>
<tr>
<td>558.1</td>
<td>P</td>
<td>X 1</td>
<td>106*</td>
</tr>
<tr>
<td>558.2</td>
<td>M</td>
<td>X 1</td>
<td>109*</td>
</tr>
<tr>
<td>826</td>
<td>P</td>
<td>X 2</td>
<td>100</td>
</tr>
<tr>
<td>848</td>
<td>P</td>
<td>X 3</td>
<td>102</td>
</tr>
<tr>
<td>960</td>
<td>M</td>
<td>X 4</td>
<td>104</td>
</tr>
</tbody>
</table>

$^1$ [www.danskeslagterier.dk](http://www.danskeslagterier.dk)

* Significant effects (P<0.05)

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$^2$ Gross margin per pen place per year based on the same feed price and an average 5 year pig price (excluding xylanase costs). All data expressed versus control set at 100
Short chain xyloligosaccharides (AXOS) derived “in vitro” from hydrolysis of wheat bran by xylanase are prebiotics.

Effect of different oligosaccharides on the concentration of bifidobacteria in the cecum of rats fed diets containing structurally different wheat-derived AXOS for 14 days.

Van Craeyveld et al. 2008
Phytate As An Anti-nutrient - Effects On Weaner Pig Performance

- 37% Daily gain (g) Control: 316, Phytic Acid (2%): 198
- 18% Daily feed intake (g) Control: 437, Phytic Acid (2%): 360
- 25% Gain:Feed (g:g) Control: 0.72, Phytic Acid (2%): 0.54

Woyengo et al 2012  Synthetic diets (casein-cornstarch) + 2% phytic acid (0.56% phytate P)
Weaning weight 7.4kg, 21 day trial
Zinc At High Levels Reduces Phytase Efficacy (Piglets 7-14 Kg)

Phytase 500 FTU/kg feed ¹ 1000 FTU/kg feed ¹

+ Zinc² 1500 mg/kg - ✓ - ✓

<table>
<thead>
<tr>
<th>Phytase</th>
<th>500 FTU/kg feed ¹</th>
<th>1000 FTU/kg feed ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Zinc² 1500 mg/kg</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>

¹ E. coli phytase n.b. measured using an assay which usually underestimates FTU’s versus other assays

² zinc oxide (ZnO) or basic zinc chloride (Zn₅Cl₂(OH)₈) * P<0.01

E. Coli Phytase From 500 To 2000 FTU/kg Feed Incrementally Improves Young Pig Performance In Presence Of High Zinc (2.5 kg/Tonne Zinc Oxide)

Bodyweight Gain (g/d, 1-28 days)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bodyweight Gain (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>548b</td>
</tr>
<tr>
<td>500 FTU/kg</td>
<td>561ab</td>
</tr>
<tr>
<td>1000 FTU/kg</td>
<td>599a</td>
</tr>
<tr>
<td>2000 FTU/kg</td>
<td>616a</td>
</tr>
<tr>
<td>4000 FTU/kg</td>
<td>608a</td>
</tr>
</tbody>
</table>

+12.4%

*Means not sharing the same superscript differ significantly (P<0.05)*

R&I Centre, Rivalea, Australia
**E. Coli** Phytase From 500 To 2000 FTU/kg Feed Incrementally Improves Young Pig Performance In Presence Of High Zinc (2.5 kg/Tonne Zinc Oxide)

Digestible energy (MJ/kg, 1-28 days)

<table>
<thead>
<tr>
<th>FTU/kg</th>
<th>Digestible Energy (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14.29bc</td>
</tr>
<tr>
<td>500 FTU/kg</td>
<td>14.22c</td>
</tr>
<tr>
<td>1000 FTU/kg</td>
<td>14.28bc</td>
</tr>
<tr>
<td>2000 FTU/kg</td>
<td>14.49ab</td>
</tr>
<tr>
<td>4000 FTU/kg</td>
<td>14.63a</td>
</tr>
</tbody>
</table>

+0.20 MJ (48 kcal) +0.14 MJ (33 kcal)

Means not sharing the same superscript differ significantly (P<0.05)

*R&I Centre, Rivalea, Australia*
Minimizing Maintenance Energy And Protein/Amino Acid Costs In The Young Pig

USE OF AN OSMOLYTE - NATURAL BETAINE
Energy Partitioning – The Importance Of ‘Maintenance’ Energy To Productive Performance In Pigs

- Maintenance: ~25%
- Production e.g. lean and fat deposition: ~31%
- Heat: ~40%
- Urine & methane: ~4%
Gut Maintenance Energy Requirements Are ~50% Of Total Maintenance Energy Requirements

Contributors include:

- **Endogenous losses**
  - Mucins
  - Sloughed gut cells
  - Endogenous enzymes

- **Immune secretions**
  - The gut – the largest immune organ in the body (Kraehenbuhl & Neutra 1992)

- **Electrolytes & maintaining osmotic balance**
  - Na\(^+\)/K\(^+\) pump (~30-60% of the energy consumption of the gut epithelium and liver)

- **Gut size, gut mucosal structure and cell turnover**
  - n.b. a heavy gut ≠ a healthy gut!

*Illustrates the importance of ‘gut health’ to productive performance*
Natural Betaine – A Role In Optimal Nutrition After Weaning?

- Chemically, betaine is the trimethyl derivative of the amino acid glycine with a formula of $(\text{CH}_3)_3\text{NCH}_2\text{COO}$ and a molecular weight of 117.2

Natural betaine offers two functions from the same molecule

- Osmoprotectant assisting in cellular water homeostasis
- Methyl group donor via transmethylation
Natural Betaine Reduces Maintenance Energy Costs

Wageningen Institute, Netherlands
Castrates (46-60kg), small groups in calorimeters, gas exchange used to estimate maintenance energy requirements (kJ ME/kg $^{0.75}$/day)

Rivalea (formerly QAF), Australia
Boars (30-55kg), individually housed, serial slaughter used to estimate maintenance energy requirements (kJ DE/kg $^{0.75}$/day)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Natural betaine (1.25kg/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wageningen</td>
<td>472</td>
<td>459 (*)</td>
</tr>
<tr>
<td></td>
<td>- 3%</td>
<td></td>
</tr>
<tr>
<td>Rivalea</td>
<td>766</td>
<td>686</td>
</tr>
<tr>
<td></td>
<td>- 10%</td>
<td></td>
</tr>
</tbody>
</table>

(*) $P<0.10$ Schrama et al (2003)

Campbell et al (1997)

Lower maintenance energy requirements for water balance - more energy available for growth and lean gain
Natural Betaine Significantly Improved (*P<0.05) Villus Height And Crypt-villus Area At 20 Days After Weaning – Improved Absorptive Area For Nutrients After Weaning

Small intestine villus height (microns)

Control: 403
Natural betaine (2kg/t): 447*

Small intestine medial crypt-villus area (microns² x 1000)

Control: 246
Natural Betaine (2kg/t): 314*

Natural Betaine Significantly Improved (*P<0.05) Muscle Depth And Tensile Strength In The Small Intestine At 20 Days After Weaning – A More Robust Gut Structure For Improved Digestion And Absorption

- Small intestine muscle depth (microns)
  - Control: 64
  - Natural betaine (2kg/t): 76*

- Small intestine tensile strength (kg)
  - Control: 0.70
  - Natural betaine (2kg/t): 0.85*

Stabilizing The Gut Microbiota In The Young Pig
Use Of A Direct Fed Microbial (DFM*) Product During Late Gestation And Lactation

- Asymptomatic herd
- 208 mixed parity sows (average parity 1.8)
  - 104 sows fed control diets
  - 104 sows fed control diets + DFM* (0.05%)  
  - Last 6 weeks of gestation & throughout lactation (range 18-25 days)

- Measurements
  - Litter size (standardized at a mean of 10.97 piglets after birth by cross-fostering within dietary treatment)
  - Piglet and litter weight gain
  - Litter size at weaning and pre-weaning mortality (%)
  - Clostridial counts in the gut of piglets on day 3 of lactation

* specially selected isolates of *Bacillus subtilis*
Use Of A Direct Fed Microbial (DFM) Product During Late Gestation And Lactation

<table>
<thead>
<tr>
<th></th>
<th>Litter size*</th>
<th>Initial litter weight* (kg)</th>
<th>Litter weaning weight (kg)</th>
<th>Litter average daily gain (kg)</th>
<th>Litter size at weaning</th>
<th>% pre-weaning mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10.95</td>
<td>15.4</td>
<td>58.5</td>
<td>2.15</td>
<td>9.56</td>
<td>12.8</td>
</tr>
<tr>
<td>DFM</td>
<td>10.99</td>
<td>16.9 (+9.7%)</td>
<td>61.9 (+5.8%)</td>
<td>2.28 (+6.0%)</td>
<td>9.86 (+3.1%)</td>
<td>10.4</td>
</tr>
<tr>
<td>P value</td>
<td>0.54</td>
<td>0.01</td>
<td>0.02</td>
<td>0.09</td>
<td>0.06</td>
<td>0.12</td>
</tr>
</tbody>
</table>

* Standardised after birth by cross-fostering, within dietary treatment
n.b. approx. 1 more pig per litter born alive in DFM sows versus control 12.2 versus 11.1 (P<0.01)  

Rosener et al (2009)
Use Of A Direct Fed Microbial (DFM) Product During Late Gestation And Lactation

Distal colon of piglets - Clostridial counts (CFU/g tissue)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>DFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts</td>
<td>$1.85 \times 10^6$</td>
<td>$5.13 \times 10^5$</td>
</tr>
</tbody>
</table>

Effect of DFM on day 3 of lactation $P<0.05$

Rosener et al (2009)
Conclusions

Effective feed additives for the pig after weaning need to:

- Minimize the pig’s maintenance energy and protein/amino acid costs
- Stabilize the gut microbiota and support the young pig’s developing immune system
- ‘Feed the gut’ to maintain gut integrity and absorptive function
- Have complementary modes-of-action – this will determine the best additive choices from a long list of ‘potentials’, particularly when reducing antibiotics & removing antibiotic growth promoters
Question and Answer

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