Alternative Feedstuffs and Feeding Programs for Nursery Pigs

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Outline

• Big Picture
  – Feed Science & Business of Feed
    • Why did alternative feedstuffs become important?
      – Why did fiber nutrition become more important?

• Feeding programs - carbohydrates
  – Starch
  – Fiber
    • Ranges for fiber content
    • Functional Properties of Fiber
  – Oligosaccharides

• Summary and Conclusions
A Problem: Feed Costs

Recently, alleviation in cost (more for corn than SBM)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Energy content</th>
<th>2005 Cost</th>
<th>2012 Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mcal NE/kg</td>
<td>$/tonne</td>
<td>$/Mcal NE</td>
</tr>
<tr>
<td>Corn</td>
<td>2.67</td>
<td>72</td>
<td>2.7</td>
</tr>
<tr>
<td>Soybean meal, 46%</td>
<td>2.09</td>
<td>220</td>
<td>10.5</td>
</tr>
<tr>
<td>Corn DDGS</td>
<td>2.34</td>
<td>55</td>
<td>2.4</td>
</tr>
<tr>
<td>Wheat midds</td>
<td>2.12</td>
<td>66</td>
<td>3.1</td>
</tr>
<tr>
<td>Fat source: AV blend</td>
<td>7.23</td>
<td>331</td>
<td>4.6</td>
</tr>
</tbody>
</table>
Maximize opportunities to include (human) non-edible feedstuffs into swine diets

- Pig is omnivorous
- Sustainability

Flexible feed formulation
Alternative Feedstuffs

- **Crops**
  - Cereal grain [consider: crops that do not make food grade]
    - Corn vs. small grains
  - Pulse (non-oilseed legume) seed
  - Oilseed

- **Co-products**
  - Biofuel Industry
    - DDGS, crude glycerol, oilseed meal or cake
  - Food Industry
    - Oilseed meal or cake, wheat co-products, sugar beet pulp, etc.
    - [Behind every food product in the supermarket, there is at least 1 co-product]
  - Fractionation

- Caution: Commodity vs. local opportunity
## Composition of Feedstuffs (%; as-fed)

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Starch</th>
<th>NSP</th>
<th>Protein</th>
<th>Fat</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat middlings</td>
<td>25</td>
<td>37</td>
<td>16</td>
<td>4</td>
<td>1.1</td>
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<td>Wheat DDGS</td>
<td>3</td>
<td>35</td>
<td>35</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Corn DDGS</td>
<td>3</td>
<td>28</td>
<td>27</td>
<td>11</td>
<td>0.8</td>
</tr>
<tr>
<td>Barley</td>
<td>54</td>
<td>18</td>
<td>11</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>14</td>
<td>17</td>
<td>47</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Field Pea</td>
<td>47</td>
<td>14</td>
<td>23</td>
<td>1</td>
<td>0.3</td>
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<tr>
<td>Wheat</td>
<td>61</td>
<td>10</td>
<td>12</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>Corn</td>
<td>63</td>
<td>10</td>
<td>9</td>
<td>4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

NSP + lignin = fiber

(CVB, 1994; Widyaratne and Zijlstra, 2007)
2 Key Phases Nursery Pigs

1. Weaning: get pigs to eat dry feed
2. Once eating well, switch to alternative feedstuffs
   • Our focus
   • Concern: Fiber & Feed Intake

(Kyriazakis and Emmans, 1995)
Weaned Pigs
Energy density and fiber content

(Beaulieu et al., 2006)

<table>
<thead>
<tr>
<th>ADF</th>
<th>4.0</th>
<th>3.2</th>
<th>2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATTDGE</td>
<td>77</td>
<td>81</td>
<td>86</td>
</tr>
</tbody>
</table>

- W d 17, d 25-41, Reducing energy: mostly replacing oat groats with barley
- Challenges paradigms: (1) Nursery pigs must eat high energy diets; (2) Nursery pigs can’t eat high fiber diets; (3) Don’t feed barley to nursery pigs
Nursery Trials at U of A
Standard protocols

• Weaned ± d 21
• Fed standard commercial diets
• 4 pigs per pen
• Genotype: Hypor
• 12 experimental unit (pens)/treatment
• Net energy, SID amino acids
• Until 2014
  – Plasma protein in commercial diets
  – Start experimental diets 1 week after weaning
• Since 2014
  – No plasma
  – For now, start most trials 2 weeks after weaning
Weaned Pigs
Wheat and barley

<table>
<thead>
<tr>
<th></th>
<th>ADG (kg)</th>
<th>ADFI (kg)</th>
<th>G:F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>3.8</td>
<td>5.4</td>
<td>6.6</td>
</tr>
<tr>
<td>HQ-barley</td>
<td>6.3</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>LQ-barley-NC</td>
<td>6.6</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>LQ-barley-C</td>
<td>6.6</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>LQ-barley-LNE</td>
<td>6.6</td>
<td>6.3</td>
<td></td>
</tr>
</tbody>
</table>

ATTDGE

|        | 80       | 74       | 75   | 76   | 77   |

(Nasir et al., 2014)

- W d 28. Barley perhaps not so bad after all; or just a bad wheat sample.
### History: Weaned Pigs

#### Solvent-Extracted Canola Meal

<table>
<thead>
<tr>
<th></th>
<th>100% SBM</th>
<th>'75/25</th>
<th>'50/50</th>
<th>'25/75</th>
<th>100% CM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADG (kg/d)</strong></td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>ADFI (kg/d)</strong></td>
<td><img src="image6.png" alt="Graph" /></td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
<td><img src="image10.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>G:F</strong></td>
<td><img src="image11.png" alt="Graph" /></td>
<td><img src="image12.png" alt="Graph" /></td>
<td><img src="image13.png" alt="Graph" /></td>
<td><img src="image14.png" alt="Graph" /></td>
<td><img src="image15.png" alt="Graph" /></td>
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</tbody>
</table>

**Performance was reduced when CM was included**

#### Diets formulated to equal DE, CP, and total Lys

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Barley</th>
<th>SBM</th>
<th>CM</th>
<th>Tallow</th>
<th>L-Lys.</th>
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</thead>
<tbody>
<tr>
<td><strong>ADG</strong></td>
<td>20</td>
<td>49.6</td>
<td>25.4</td>
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<td>-</td>
<td>.10</td>
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<tr>
<td><strong>ADFI</strong></td>
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<td>45.6</td>
<td>19</td>
<td>8.8</td>
<td>1.5</td>
<td>.12</td>
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<tr>
<td><strong>G:F</strong></td>
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<td>41.4</td>
<td>12.7</td>
<td>17.6</td>
<td>3.3</td>
<td>.13</td>
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<td></td>
<td>20</td>
<td>37.2</td>
<td>6.3</td>
<td>26.5</td>
<td>5.0</td>
<td>.14</td>
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<tr>
<td></td>
<td>20</td>
<td>33</td>
<td>-</td>
<td>35.3</td>
<td>6.7</td>
<td>.15</td>
</tr>
</tbody>
</table>

**• Glucosinolates (ANF)**
**• Palatability**
**• Fiber**
**• Lower AA digestibility**

SE Canola meal: 10 μmol total glucosinolates/g
One diet; steam pelleted

(Baidoo et al., 1987)
Weaned Pigs
Solvent-Extracted Canola Meal

Performance was not reduced when solvent-extract CM was included

Diets formulated to equal NE and SID AA

<table>
<thead>
<tr>
<th></th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
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<td>57.9</td>
<td>57.8</td>
<td>56.7</td>
<td>56.1</td>
<td>55.5</td>
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<tr>
<td>L/PC/F</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>SBM</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>CM</td>
<td>-</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Oil</td>
<td>3</td>
<td>3.5</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
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<tr>
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<td>-</td>
<td>.08</td>
<td>.15</td>
<td>.23</td>
<td>.30</td>
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<td>5.9</td>
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<tr>
<td>ATTDGE</td>
<td>86</td>
<td>85</td>
<td>84</td>
<td>84</td>
<td>82</td>
</tr>
</tbody>
</table>

- Weaned at 3 wk
- Start diets 1 wk later for 4 wk
- Other feedstuffs?
  - Palatability
  - “Buffer”
- Feedstuffs change
  - Glucosinolate

SE Canola meal: 3.84 μmol total glucosinolates/g
One diet; steam pelleted

Landero et al., 2011

20% canola meal reduced feed price by $11.9 per MT and feed cost per unit of body weight gain by 2 cents/kg.
Weaned Pigs
Canola Expeller

Performance was not reduced when expeller-pressed CM was included

Diets formulated to equal NE and SID AA

<table>
<thead>
<tr>
<th></th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>55.9</td>
<td>56.2</td>
<td>56.6</td>
<td>57.0</td>
<td>57.4</td>
</tr>
<tr>
<td>L/PC/F</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
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</tr>
<tr>
<td>SBM</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>EPCM</td>
<td>-</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Oil</td>
<td>5.0</td>
<td>4.5</td>
<td>4.0</td>
<td>3.5</td>
<td>3.0</td>
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<tr>
<td>L-Lys.</td>
<td>.02</td>
<td>.09</td>
<td>.16</td>
<td>.22</td>
<td>.29</td>
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<td>3.8</td>
<td>4.8</td>
<td>5.4</td>
<td>6.0</td>
</tr>
<tr>
<td>ATTDGE</td>
<td>85</td>
<td>85</td>
<td>84</td>
<td>83</td>
<td>83</td>
</tr>
</tbody>
</table>

EP Canola meal: 10.87 μmol total glucosinolates/g
One diet; steam pelleted

20% expeller-pressed canola meal reduced feed price by $29.8 per MT and feed cost per unit of body weight gain by 4.2 cents/kg.
Weaned Pigs
Canola Cake

Performance was not reduced when canola cake was included

Diet formulations to equal NE and SID AA:

<table>
<thead>
<tr>
<th></th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
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<td>15</td>
<td>15</td>
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</tr>
<tr>
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<td>12</td>
<td>6</td>
<td>-</td>
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<tr>
<td>CC</td>
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<td>15</td>
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<tr>
<td>Oil</td>
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<td>3.6</td>
<td>2.7</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>L-Lys.</td>
<td>.09</td>
<td>.21</td>
<td>.33</td>
<td>.45</td>
<td>.57</td>
</tr>
</tbody>
</table>

- Other feedstuffs?
  - Palatability
  - “Buffer”

Canola cake: 11.1 μmol total glucosinolates/g
Two diets; first diet cold pelleted

Canola cake has even more value for pork producers

(Zhou et al., 2015)
Also 2016 BPS poster
15% wheat DDGS reduced feed price by $14.60 per MT and feed cost per unit of body weight gain by 2.07 cents/kg. More recent trial, less impact on performance.
Weaned Pigs
Wheat Millrun

<table>
<thead>
<tr>
<th>ADF</th>
<th>3.4</th>
<th>4.0</th>
<th>4.2</th>
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<td>ATTDGE</td>
<td>84</td>
<td>83</td>
<td>83</td>
<td>82</td>
<td>81</td>
</tr>
</tbody>
</table>

Linear $P < 0.01$

(Garcia et al., 2015)
Weaned Pigs (wk 1-5)

Field pea

- ADFI (kg/d)
- ADG (kg/d)
- G:F

$L_P > 0.05$

(Landero et al., 2014)
Weaned Pigs (wk 1)
Field pea

Limitations exist in young pigs: feed technologies (Landero et al., 2014)
Weaned Pigs (wk 5)
Field pea

Compensatory gain & starch profile

(Landero et al., 2014)
Weaned Pigs
Challenging model: Sugar beet pulp

<table>
<thead>
<tr>
<th>ADG (kg)</th>
<th>ADFI (kg)</th>
<th>G:F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>6%</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>12%</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>18%</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>24%</td>
<td>10.1</td>
<td></td>
</tr>
</tbody>
</table>

ATTDGE:
- 87
- 86
- 84
- 83
- 82

L P < 0.05
L P < 0.001
Q P < 0.01

(Wang et al., 2016)
Take Home Message

- Pigs can successfully convert a wide array of feedstuffs into pork
- Once eating dry feed well, weaned pigs can handle alternative feedstuffs better than being credited for
- Fiber shouldn’t scare you
- Use modern feed evaluation to increase flexibility in feed formulation
- Let performance targets and economics drive your feed formulation
Carbohydrates - Definition

Plant Carbohydrates

Cell Contents
Non-Structural Carbohydrates
- Organic Acids
- Sugars
- Starch
- Fructans

Cell Wall
Structural Carbohydrates
- Pectin
- β-Glucans
- Hemicellulose
- Cellulose
- Lignin

Neutral Detergent Fiber
Acid Detergent Fiber

Non-fiber Carbohydrates
Nonstructural Carbohydrates

Not 100% correct, because some starch may act like fiber (resistant starch)
Sugar, disaccharide (DP2), oligosaccharide (DP3-9), polysaccharide (DP≥10)
Crude fiber is not useful to accurately describe fiber
- Fiber and Feed formulation – Consider Energy and AA

Net energy

<table>
<thead>
<tr>
<th>No.</th>
<th>Equation</th>
<th>$R^2$</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>$NE = 0.700 \times DE + 1.61 \times EE + 0.48 \times ST - 0.91 \times CP - 0.87 \times ADF$</td>
<td>0.97</td>
<td>42</td>
</tr>
</tbody>
</table>

(Noblet et al., 1994; NRC, 2012)

Limits for carbohydrate analyses

(Fairbairn et al., 1999)
Ileal-cannulated pig

- Small intestine
- Cecum
- Stomach
- Ileal cannula
- Rectum
- Colon

Total extent of digestion
- Can separate between small and large intestine
Portal-vein catheterized pig

Net nutrient absorption or
Net insulin and incretin secretion =
(Portal – Carotid conc.) x blood flow

Portal vein

Liver

Pancreas

G.I. Tract

Mesenteric artery

Carotid artery

Upper limbs

Head

Kinetics of digestion
# Starch Chemistry

<table>
<thead>
<tr>
<th>Amylose</th>
<th>0 %</th>
<th>18%</th>
<th>29%</th>
<th>63%</th>
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</thead>
<tbody>
<tr>
<td>Granule</td>
<td>12 sq µm</td>
<td>19 sq µm</td>
<td>229 sq µm</td>
<td>35 sq µm</td>
</tr>
<tr>
<td>Crystallinity</td>
<td>40%</td>
<td>36%</td>
<td>30%</td>
<td>24%</td>
</tr>
<tr>
<td>RS</td>
<td>3%</td>
<td>34%</td>
<td>61%</td>
<td>85%</td>
</tr>
</tbody>
</table>

RS = resistant starch

(Van Kempen et al., 2010; Regmi et al., 2011ab; J. Nutr.)
In vivo - Net Glucose Absorption

Glucose, mmol/min

4 x 4 Latin Square; 7-day period; portal & carotid blood

Reduction peak by ~50%

(P < 0.05)

(Rapid > Slow)

(Rapid > M-Rapid = M-slow > Slow)

(Van Kempen et al., 2010; J. Nutr.)
Functional properties of NSP, such as viscosity & fermentability, important for physiological effects of NSP in the gut (Dikeman and Fahey, 2006).

- **NSP**
  - Stomach & Small intestine
  - Large intestine
  - Viscoisty
  - Fermentability

Nutrient digestion, absorption and hormones kinetics: **Reduce**

Microbial fermentation, SCFA production and absorption, gut health: **Increase**

Move beyond soluble vs. insoluble fiber
Digesta kinetics


Mean retention time

V - P > 0.05
F, P < 0.05
V × F, P < 0.05
Functional Characteristics  
- Fiber fermentation kinetics -

Fitted kinetics parameters (means) on the gas accumulation recorded for the different hydrolyzed substrates incubated with pig faecal inoculums

- L, lag time (h).
- T/2, half-time to asymptote (h).
- $\mu$, fractional rate of degradation (h$^{-1}$) at t = T/2
- $G_f$, maximum gas volume (ml per g DM incubated).

- Wheat bran
- Solkafloc
- Field pea
- Pea hulls
- Pea inner fiber
- Sugar beet pulp
- Flax seed meal
- Corn DDGS

(Jha et al. 2011)
Mean net flux of SCFA absorption

Propionate and Butyrate absorption rate increased by β-glucan fermentable substrate; applied swine nutrition

Fiber (Resistant Starch) & Gut Health

Enterobacteriaceae, log gene copies/d

Bifidobacteria, log gene copies/d

Ileal starch flow, log g/day

R² = 0.27; P < 0.01

R² = 0.00; P = 0.92

(Fouhse et al., 2016 BPS poster)
Undigested proteins may become fermentable substrate
Amine production

(Jeaurond et al. 2008)
Exopolysaccharides

- Reuteran and levan, produced by *Lactobacillus reuteri*, may reduce the occurrence of ETEC-related diarrhea
  - Function as imitators of carbohydrate receptors
  - Prevents ETEC adhesion to intestinal wall\(^1,2\)
  - Reduces subsequent loss of fluid

\(^1\)Kiarie et al., 2008
\(^2\)Kiarie et al., 2010

Images: Korakli and Vogel, 2006
Net fluid absorption

Means with uncommon letters differ, $P < 0.01$
Net fluid absorption

**P < 0.01 and †P < 0.1

![Graph showing net fluid absorption for different substances: Dextran, Inulin, Levan, and Reuteran. The graph compares PBS and ETEC groups.](image-url)
Summary and Conclusions

• Carbohydrate nutrition is becoming more important
  • High fiber feedstuffs
  • Starch, fiber, oligosaccharide characteristics

• Especially, fermentability are important fiber properties for applied swine nutrition
  • Effects energy use (SCFA) but also value-added attributes

• Starch and fiber analyses should be improved
  • Explain kinetics and fermentability, include in feed formulation
  • Include resistant starch

Detailed understanding of characteristics will support
• The transition of swine to diets high in fiber content
• Use of feedstuffs to control gut health
Acknowledgments

Colleagues

- Graduate students
  - Xun Zhou,
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Alternative Feedstuffs and Feeding Programs for Nursery Pigs

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Swine nutrition research
• Basic carbohydrate nutrition
• Feedstuff development
• Rapid feed quality evaluation

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