FEED AND OTHER FACTORS THAT DRIVE FEED EFFICIENCY

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Ames, IA

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Things are not always what they seem
Things are not always what they seem
### Feed efficiency comparison

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial wt, lb</td>
<td>55</td>
<td></td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Final wt., lb</td>
<td>275</td>
<td></td>
<td>282</td>
<td></td>
</tr>
<tr>
<td>Feed:gain</td>
<td>2.67</td>
<td></td>
<td>2.72</td>
<td></td>
</tr>
</tbody>
</table>
Overall Objective

Increase **nutrient utilization** and **feed efficiency** in pork production, thereby strengthening the competitiveness of the pork industry and reducing its demand on grains and proteins, through focused and integrated initiatives in research and extension.

**PI and co-PIs**

**Iowa State University**
- **Nutrition**
  - John Patience (PI)
  - Nick Gabler
  - Brian Kerr (USDA)
- **Physiology**
  - Lloyd Anderson
- **Statistics**
  - Peng Liu
  - Dan Nettleton

**Kansas State University**
- **Genetics**
  - Jack Dekkers
  - John Mabry
  - Max Rothschild
- **Meat Science**
  - Chris Tuggle
- **Statistics**
  - Steven Lonergan
  - Elisabeth Huff-Lonergan

**Michigan State University**
- **INRA, France**
  - Janice Siegfard
  - Andrew van Kessel
  - Helene Gilbert
  - Roger Campbell, Frank Dunshea
AFRI Feed Efficiency project

Integrated:
1) Research in swine genomics, quantitative genetics, transcriptomics, proteomics, nutrition, immunology, bioinformatics, statistics, microbiology, physiology, meat science and behavior,
2) Diverse extension approaches
3) Training opportunities at the graduate and undergraduate levels
U.S. pig industry

- Gross receipts of $23.4 billion
- Total sales of 112 million head
  - Exports represent 26% of total production
- Responsible for 547,800 U.S. jobs
- COP (2015) ≈ $66/cwt
- Total feed consumed by US hog industry per year ≈ 45 million tons
- Value of hog feed ≈ $10 billion
“Typical” feed efficiency numbers

- **Wean-to-finish**
  - Feed conversion (live): 2.60
  - Feed cost: $0.28 to $0.30 per lb gain

- **Whole-herd**
  - Feed conversion (live): 2.90
  - Feed cost: $0.33 to $0.34 per lb gain
  - Sow herd feed charged to market hogs sold
Impact of improvements in feed efficiency - 1

- A 1% improvement in feed efficiency:
  - 450,000 tons of feed
  - $100 million
- A 1 point improvement in feed efficiency:
  - 153,000 tons of feed
  - $34 million

Assumes whole herd FC of 2.9 and average feed cost of $220/t
Impact of improvements in feed efficiency - 2

- 970 million bushels of corn is amount used by U.S. pork industry
  - 9.3% of total U.S. corn crop

- 1 point in FC represents 3.3 million bushels of corn

- 3.3 million bushels of corn represents 20,625 acres

Sow productivity changes over last 38 years, lb pork sold per sow

Source: Pork Facts, 2014 (Pork Check-Off)
Without the improvement in sow output since 1975, to produce the same amount of pork today, would require …..
Without the improvement in sow output since 1975, to produce the same amount of pork today, would require **9.22 million more sows (15.0 vs 5.76 million)**....
Without the improvement in sow output since 1975, to produce the same amount of pork today, would require 9.22 million more sows (15.0 vs 5.76 million) with an added feed cost alone of $2.766 billion or $22.67 per pig sold.
A 1% improvement in feed efficiency:
450,000 tons of feed
$100 million

**BUT,** FEED EFFICIENCY **CAN BE LOOKED AT IN OTHER WAYS**

A 1 point improvement in feed efficiency:
153,000 tons of feed
$34 million
Our definition of “efficiency” has changed over the years (centuries)

- **Forage to convert “food” of no or poor value (roots, nuts, grass, etc.) into products of value to humans: food, leather, etc.**
  - Efficiency not measured

- **On subsistence farm, convert low value materials into food, etc and generate cash to purchase goods not produced on the farm**
  - Efficiency = cash income

- **On increasingly specialized farm, convert grain into cash for profit and raise standard of living of farm family**
  - Efficiency = productivity

- **On mixed farm, convert grain into cash to pay bills, cover other farm costs and provide food, etc to the farm family**
  - Efficiency = cash income

- **On heavily capitalized farm, cover expenses and provide expected return on investment**
  - Efficiency = cash income

Today: Efficiency = financial returns
The best feed efficiency does not necessarily mean the best financial outcome.

We want to strive for **optimal** feed conversion, not **maximal** feed conversion.
Feed efficiency concepts

• Optimizing feed efficiency contributes greatly to overall farm success

• Feed conversion is a very complex subject

• Feed conversion should not be a management target used in isolation. – It must be considered in the context of other performance and financial outcomes
Feed efficiency is influenced by many factors

- **Feed composition**
  - Energy, amino acid concentration, nutrient balance
  - Gross deficiencies of other nutrients
  - Feed processing: grinding, pelleting, enzymes
  - Feed additives

- **Environmental factors**
  - Temperature
  - Health (huge),
  - Access to feed

- **Pig**
  - Growth rate, protein:lipid ratio, starting and final weight, mortality
International Conference on Feed Efficiency in Swine - 2015

- October 21 & 22, 2015
- Omaha Hilton Hotel, Omaha, NE
Pigs selected for improved feed efficiency digest feed more efficiently

<table>
<thead>
<tr>
<th></th>
<th>More efficient</th>
<th>Less efficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>87.3</td>
<td>85.9</td>
<td>0.0006</td>
</tr>
<tr>
<td>Energy, %</td>
<td>86.9</td>
<td>85.4</td>
<td>0.0006</td>
</tr>
<tr>
<td>Nitrogen, %</td>
<td>88.3</td>
<td>86.1</td>
<td>0.003</td>
</tr>
<tr>
<td>Diet ME, Mcal/lb</td>
<td>1.53</td>
<td>1.50</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

Source: Gabler, 2015
Why are pigs that are more efficient more efficient?

Source: Gabler, 2015
Response to a PPRS challenge: Average Daily Gain (g): more efficient/less efficient

Challenge Status*RFI Line: P = 0.04

Source: Rowland et al, 2015
In-feed antibiotics and performance

• Nursery: pig weight increased by about 1.5 to 2 lb when using appropriate growth promoting antibiotics
• Finishing: Limited impact on ADG
• In modern, multi-site swine operations little impact of feed grade growth promoting antibiotics on feed efficiency

Source: DeRouchey et al, 2015
## Economics of lower energy diets

<table>
<thead>
<tr>
<th>Parameter/pig</th>
<th>Corn/ SBM 0%</th>
<th>-50 kcal NE 3.75%</th>
<th>-100 Kcal NE 7.50%</th>
<th>-150 kcal NE 15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed cost in trial</td>
<td>$63.89</td>
<td>$62.64</td>
<td>$63.80</td>
<td>$61.16</td>
</tr>
<tr>
<td>Carcass gain needed, lb</td>
<td>-</td>
<td>4.0</td>
<td>3.1</td>
<td>8.8</td>
</tr>
<tr>
<td>Days needed</td>
<td>-</td>
<td>2.8</td>
<td>2.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Cost of space</td>
<td>-</td>
<td>$0.39</td>
<td>$.30</td>
<td>$.88</td>
</tr>
<tr>
<td>Cost of additional feed</td>
<td>-</td>
<td>$2.40</td>
<td>$1.91</td>
<td>$5.28</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td><strong>$63.89</strong></td>
<td><strong>$65.43</strong></td>
<td><strong>$66.00</strong></td>
<td><strong>$67.32</strong></td>
</tr>
<tr>
<td>Difference from control</td>
<td>-</td>
<td>$1.54</td>
<td>$2.11</td>
<td>$3.43</td>
</tr>
</tbody>
</table>

Source: Frederick and Cline, 2015
Components of carbohydrates

Plant Carbohydrates

Cell Contents
- Starch
- Disaccharides
- Oligosaccharides including fructooligosaccharides
- Fructan polysaccharides
- Resistant starch

Cell Wall
- B-glucans
- Pectins and Gums
- Hemicellulose
- Cellulose
- Lignin

Analytical determination

Starch
Sugars

Water-soluble carbohydrates
Non-starch polysaccharides (NSP)

Non-structural carbohydrates

ADL
NDF

ADF
SDF
IDF
Total dietary fiber (TDF)

Indicates that recovery of included components may be incomplete

Source: Dr. George Fahey, with permission
Effect of corn quality on apparent ileal and apparent total tract digestibility, and hindgut fermentation by difference

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AID, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE</td>
<td>79.12</td>
<td>80.18</td>
<td>80.20</td>
<td>79.67</td>
<td>1.04</td>
<td>0.744</td>
</tr>
<tr>
<td>DM</td>
<td>77.46</td>
<td>78.22</td>
<td>78.86</td>
<td>78.52</td>
<td>1.11</td>
<td>0.686</td>
</tr>
<tr>
<td><strong>Fermentation, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE</td>
<td>5.59</td>
<td>5.48</td>
<td>2.76</td>
<td>3.79</td>
<td>1.49</td>
<td>0.092</td>
</tr>
<tr>
<td>DM</td>
<td>6.30</td>
<td>6.50</td>
<td>3.67</td>
<td>4.52</td>
<td>1.69</td>
<td>0.113</td>
</tr>
<tr>
<td><strong>ATTD, %</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE</td>
<td>84.39</td>
<td>85.68</td>
<td>83.15</td>
<td>83.60</td>
<td>1.05</td>
<td>0.008</td>
</tr>
<tr>
<td>DM</td>
<td>83.47</td>
<td>84.82</td>
<td>82.82</td>
<td>83.25</td>
<td>1.11</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Source: Newman and Patience, 2014
Heat stress may reduce maintenance energy requirement in grow-finish pigs

<table>
<thead>
<tr>
<th></th>
<th>65 to 130 lb</th>
<th></th>
<th>130 to 200 lb</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TN</td>
<td>HS</td>
<td>TN</td>
<td>HS</td>
</tr>
<tr>
<td>ME_{intake} (Mcal/d)</td>
<td>7.83</td>
<td>6.82</td>
<td>8.75</td>
<td>7.05</td>
</tr>
<tr>
<td>ME_{protein} (Mcal/d)</td>
<td>1.75</td>
<td>1.72</td>
<td>1.64</td>
<td>1.26</td>
</tr>
<tr>
<td>ME_{fat} (Mcal/d)</td>
<td>2.70</td>
<td>2.31</td>
<td>3.43</td>
<td>2.54</td>
</tr>
<tr>
<td>ME_{maintenance} (Mcal/d)</td>
<td>3.38</td>
<td>2.79</td>
<td>3.67</td>
<td>3.25</td>
</tr>
</tbody>
</table>

Difference: -0.590 Mcal/d, -0.430 Mcal/d

Source: Baumgard, 2015
Stress, gut function and feed efficiency

- Common stressors have marked, deleterious influence on gut barrier function
  - Increased intestinal permeability
  - Immune cell activation
  - Hypersecretion

- Stress and impaired gut function can negatively influence feed efficiency
  - Impaired digestive and absorptive processes
  - Persistent gut immune system activation
  - Changes in microbiota

Source: Moeser, 2015
## Factors affecting pellet quality

<table>
<thead>
<tr>
<th>Factor</th>
<th>Improvement in PDI, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition of 15% wheat to a corn-soybean meal diet&lt;sup&gt;1&lt;/sup&gt;</td>
<td>11.6</td>
</tr>
<tr>
<td>Addition of a pellet binder at 1.25% to corn-SBM diet&lt;sup&gt;1&lt;/sup&gt;</td>
<td>12.5</td>
</tr>
<tr>
<td>Increase conditioning temperature by 10F&lt;sup&gt;1&lt;/sup&gt;</td>
<td>10.0</td>
</tr>
<tr>
<td>Reducing fat in the mixer from 1% to 0%&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5.0</td>
</tr>
<tr>
<td>Reducing particle size from 665 to 500 microns&lt;sup&gt;2&lt;/sup&gt;</td>
<td>14.5</td>
</tr>
<tr>
<td>Increase mash moisture from 12 to 14.5%&lt;sup&gt;3&lt;/sup&gt;</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<sup>1</sup> Winowski, 1989;  <sup>2</sup> McElhinney, 1992;  <sup>3</sup> Greer and Fairchild, 1999

Source: Borg, 2015
Influence of shaking time, sieve agitators and flow agent on particle size measurement

<table>
<thead>
<tr>
<th>Time, min</th>
<th>Agitator</th>
<th>Flow agent</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Y</td>
<td>N</td>
<td>2.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Y</td>
<td>Y</td>
<td>2.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>N</td>
<td>N</td>
<td>2.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>Y</td>
<td>2.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>Y</td>
<td>2.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Woodworth et al., 2015
Optimize barn temperature

• Lower critical temperature for 50 lb pig is ~75°F; for 150 lb pig is ~60°F

• Maximum desirable temperature for a 50 lb pig is 90°F; for a 200 lb pig is ~81°F

Source: Renaudeau, 2015
Approach to group housing sows

• Accurate feed intake
  – Electronic sow feeders
• Reduce social stresses
  – Larger group size
  – More floor space per sow (24 ft²/sow)
  – Fewer sows per feeder (45 per ESF)
• Training
  – Start at 10 weeks (GDU)
  – Use trust, not fear
• Heat detection
  – Electronic
• Sow management
  – Electronic sorting
  – Dynamic groups

Source: Coleman and Friedel, 2015
Effect of heat stress during gestation on grow finish performance

• Offspring of sows exposed to heat stress in gestation
  – Altered body composition and circulating insulin levels

• Prenatal exposure to heat stress resulted in:
  – Lower protein in carcass
  – More fat in the carcass
  – Altered gene expression patterns in LD muscle, fat and liver

Source: Ross et al., 2015
Typical checklist for feed efficiency

- Reduce feed wastage (2% age pt = $1.44/pig)
- Reduce mortality (1% reduction = ~1% gain)
- Ensure next fill of pigs starts with correct diet
- Increased dietary NE: almost always improves F:G; usually but not always improves ADG – BUT is it economical?
- Reduce particle size: 100µ = ~4 pt in F:G = $1.20/pig
Checklist for feed efficiency

- Feed restriction: not recommended due to slower growth
- Optimize temperature: 50 lb = 75°F; 150 lb = 60°F
- Various feed additives
- Timely euthanasia
- Elevate average herd parity
But that is not the whole story of the AFRI Feed Efficiency Project

Serendipity stepped in to help out as well
History of ISU SCID pig discovery

- Project Goal: test tolerance to stressors in the efficient Residual Feed Intake line
- Challenged ~200 weaned pigs at KSU with PRRSv
  - Four weaned piglets from low RFI line died shortly after arrival (2 before, 2 after infection)
  - Routine necropsy identified:
    - Very small thymus and lymph nodes
    - Abnormal histopathology of thymus, lymph nodes, spleen, tonsils, and Peyer’s patches
    - No detectable antibodies
- Consistent with symptoms of SCID!

Source: Dr. Chris Tuggle, with permission
Major values of a SCID pig

• Lack of an immune system means the body cannot prevent xenograft growth
  • Xenograft- insertion of cells from another species

• An *in vivo* pre-clinical test system- available now for a large animal
  1. Test therapies on human-specific pathogens that require a immunodeficient host
     - Linda Saif + human norovirus
  2. Test drugs to kill cancer cells *which can grow in vivo*
     - Human cancer can survive (Basel et al. 2012)
  3. Test human stem-cell-derived therapeutics
     - Stability, Efficacy in large animal model
     - Human iPSC survival reported by Missouri group for *RAG2* (Lee et al. 2014)

• In (future) humanized model; vaccine testing, human immunity interactions with pathogens, stem cells.

Source: Dr. Chris Tuggle, with permission
Thank you

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.

www.swinefeedefficiency.com
Thank you