Impact of feeding biofuels co-products on pork fat quality

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“Pigs are what they eat”

- Diet fatty acid (FA) composition affects FA profile in pork fat
- FA composition varies among adipose tissue sites
  - IV of backfat > belly fat and jowl fat > loin fat
- Dietary FA composition has a greater impact on:
  - High lean genotypes (low backfat)
  - Gilts
Estimated use of DDGS in U.S. swine diets (2001-2008)
What is different about feeding grower-finisher pigs today?

- **DDGS (~ 10% corn oil)**
  - ~ 3 - 4 million MT is consumed in U.S. pork industry
    - ~85% is used in G-F diets
      - Fed at levels up to 40% of the diet
      - Has resulted in $3 to $6/market hog feed cost savings

- **Reduced oil corn co-products**
  - Becoming more available
  - Limited information about feeding value
  - Less concerns about pork fat quality but energy content is reduced
What is the main concern?

- The dietary level and feeding duration of unsaturated fatty acids

- Linoleic acid (C18:2)
  - Represents ~ 60% of fatty acids in corn oil
  - Reduces the omega 6:omega 3 ratio in pork fat
  - May contribute to reduced shelf life of fresh pork
  - May cause metabolic oxidation imbalance
  - May increase the need for vitamin E or other dietary antioxidants
Other emerging biofuels co-products

- Crude glycerol may become more available depending on:
  - Sustainability of the biodiesel industry
  - Economics relative to other dietary energy sources
  - Availability of supply
  - Methanol content (< 150 ppm)

- Growing interest in feeding liquid co-products from the ethanol industry
  - Steep water (wet milling)
  - Condensed distillers solubles (dry grind)
Crude glycerol is a by-product of biodiesel production.
### Nutrient composition of biofuels co-products (DM basis)

<table>
<thead>
<tr>
<th>Co-Product</th>
<th>ME, kcal/kg</th>
<th>Crude fat, %</th>
<th>ADF, %</th>
<th>NDF, %</th>
<th>Lysine, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDGS¹</td>
<td>3,414 - 4,141</td>
<td>10.2 - 12.1</td>
<td>8.6 - 14.4</td>
<td>33.4 - 49.1</td>
<td>1.0 - 1.3</td>
</tr>
<tr>
<td>RO-DDGS¹</td>
<td>3,650</td>
<td>3.2</td>
<td>15.8</td>
<td>51.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Dried CDS¹</td>
<td>4,525</td>
<td>11.8</td>
<td>0.50</td>
<td>2.3</td>
<td>1.1</td>
</tr>
<tr>
<td>DH-DG Corn¹</td>
<td>4,316</td>
<td>0.2</td>
<td>0.50</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Germ meal¹</td>
<td>3,417</td>
<td>2.4</td>
<td>12.5</td>
<td>61.1</td>
<td>1.2</td>
</tr>
<tr>
<td>HP-DDG¹</td>
<td>3,676 – 4,606</td>
<td>2.9 – 7.0</td>
<td>12.6 – 25.4</td>
<td>32.0 – 51.1</td>
<td>1.2 – 1.6</td>
</tr>
<tr>
<td>LS – DDG²</td>
<td>2,959</td>
<td>8.8</td>
<td>20.4</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Glycerol³</td>
<td>3,207</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Corn ME (kcal/kg) = 3,843 (NRC, 1998)

¹Data from Anderson et al. (2009)
²Data from Amaral et al. (2009)
³Data from Lammers et al. (2008)
Nutrient content of corn condensed solubles and corn steep water (DM basis)
Current Pork Fat Quality Standards

- Not well defined and questionable
  - Based on Iodine Value (IV)
    - ratio of unsaturated:saturated fatty acids

- Suggested maximum IV
  - 70 – Danish Meat Research Institute
  - 70 – National Pork Producers Council
  - 74 – Boyd et al. (1997)

- Various adipose tissue sites are affected differently by dietary fatty acid composition
Effects of Feeding Grower-Finisher Diets Containing DDGS on IV of Backfat and Belly Fat

Fat depot location main effect (P < 0.05)
DDGS main effect (P < 0.05)
DDGS linear effect (P < 0.05)
White et al., 2009
Effects of feeding 0, 20, and 40% DDGS diets on C18:2 and n-6:n-3 ratio in belly fat

DDGS main effect (P < 0.05)
DDGS linear effect (P < 0.05)

White et al., 2009
Questions

- What should the standards be for U.S. pork fat quality?
- Is IV the best criteria?

  - If the answer is yes…
    - How do you measure it on a commercial harvest/processing facility?
    - How is IV measured and/or calculated?
    - What adipose tissue depot should be used?
    - What is the maximum IV for acceptable pork fat quality?

  - If the answer is no, what criteria do you use?
    - Belly firmness?
      - Durometer?
    - Subjective appearance? (at what temperature?)
    - Others?
What is the impact from feeding DDGS to grower-finisher pigs?
### Summary of growth performance responses from feeding levels up to 30% DDGS to grower-finisher pigs

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>N</th>
<th>Increased</th>
<th>Reduced</th>
<th>Not Changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADG</td>
<td>25</td>
<td>1</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>ADFI</td>
<td>23</td>
<td>2</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Gain/Feed</td>
<td>25</td>
<td>4</td>
<td>5</td>
<td>16</td>
</tr>
</tbody>
</table>

Stein and Shurson, 2009
### Summary of carcass characteristic responses from feeding levels up to 30% DDGS to grower-finisher pigs

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>N</th>
<th>Increased</th>
<th>Reduced</th>
<th>Not Changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressing %</td>
<td>18</td>
<td>0</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Backfat thickness</td>
<td>15</td>
<td>0</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Loin depth</td>
<td>14</td>
<td>0</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>% Carcass lean</td>
<td>14</td>
<td>0</td>
<td>1</td>
<td>13</td>
</tr>
</tbody>
</table>

Stein and Shurson, 2009
Increasing Dietary Levels of DDGS MAY Reduce Carcass Dressing Percentage

Xu et al. (2009)
Linear effect (P < 0.01)
## Summary of belly quality characteristics from feeding levels up to 30% DDGS to grower-finisher pigs

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>N</th>
<th>Increased</th>
<th>Reduced</th>
<th>Not Changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly thickness</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Belly firmness</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Iodine value</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Stein and Shurson, 2009
Effects of feeding 0, 10, 20, and 30% DDGS diets on belly firmness (Xu et al., 2009)

D10 vs. D0 (P > 0.05)
D20 < D0 (P < 0.05)
D30 < D0 (P < 0.05)
Effects of feeding 0, 10, 20, and 30% DDGS diets on C18:2 content of pork fat (Xu et al., 2009)

Linear effect of DDGS for all fat depot sites (P < 0.01)
Diet × site (P < 0.01)
Effects of feeding 0, 10, 20, and 30% DDGS grower-finisher diets on iodine value of pork fat (Xu et al., 2009)

Linear effect of DDGS level for all fat depot sites ($P < 0.01$)
Diet × site ($P < 0.01$)
Effects of feeding 0, 10, 20, and 30% DDGS diets on fatty acid content of pork fat (Xu et al., 2009)

- **Linear increase**
  - PUFA
  - IV
    - Backfat (58, 63, 68, 72)
    - Belly fat (61, 65, 69, 72)
    - Loin fat (52, 57, 57, 58)

- **Linear decrease**
  - monounsaturated fatty acids
  - saturated fatty acids
No differences in:

- belly thickness

- belly fat color
  - Japanese color score
  - Minolta L*, a*, b*

- backfat color
  - Japanese color score
  - Minolta a*, b* (lower L* for pigs fed the 20% and 30% DDGS diets)
Effects of feeding 0, 10, 20, and 30% DDGS grower-finisher diets on loin characteristics (Xu et al., 2009)

- No difference in:
  - ultimate pH
  - subjective color score
  - drip loss on day 0, 14, 21, or 28 post-harvest
  - lipid oxidation in loins at 28 days of shelf storage

- Linear reduction in
  - firmness
  - marbling
  - Minolta a* and b*
  - **But ALL within current accepted NPPC quality standards**
Effects of feeding 0, 10, 20, and 30% DDGS diets on fat stability of pork loins (TBARS, mg malonaldehyde/kg) (Xu et al., 2009)

No significant differences among dietary treatments.
Effects of feeding 0, 10, 20, and 30% DDGS diets on sensory characteristics of cooked pork loins

(Xu et al., 2009)

No significant differences among dietary treatments.
Effects of feeding 0, 10, 20, and 30% DDGS diets on sensory characteristics of cooked pork loins

(Xu et al., 2009)

No significant differences among dietary treatments.
No differences in:
- Cooking yield
- Crispiness
- Off-flavor
- Overall acceptability

- Quadratic effect for flavor (P < 0.05)
- Linear effect for tenderness (P < 0.05)
- Linear and quadratic effect for fattiness (P < 0.01)

Flavor: high = intense
Tenderness: high = tough
Fattiness: high = fatty
The Positives

Feeding diets containing up to 30% DDGS has no adverse effects on:

- growth performance
- carcass backfat thickness
- % carcass lean
- belly thickness
- backfat and belly fat color
- loin muscle characteristics (met current NPPC target values)
- loin fat oxidation
- loin sensory characteristics
- bacon sensory characteristics
The Negatives

- Yield was linearly reduced (77.9 to 76.7%)
- Belly firmness was linearly reduced
- Bacon appears “greasy” (30% DDGS)
- PUFA content and IV of pork fat were linearly increased
  - highest IV = 72 (30% DDGS)
  - > current NPPC standard of 70
  - < 74 (IV threshold suggested by Boyd et al., 1997)

- Depending on pork fat quality standards used, maximum usage rate of DDGS in grower-finisher swine diet can be 30%.
Diet formulation and feeding strategies to improve pork fat quality

- Withdrawing DDGS from the diet before harvest?
- Impact of feeding wheat and barley based diets?
- Feeding reduced corn oil co-products
- Adding conjugated linoleic acid?
- Formulate diets based on iodine product value?
- Add crude glycerol to DDGS diets?
- Add saturated supplemental fat sources (e.g. tallow) to DDGS diets?
Effect of feeding 15 or 30% DDGS diets and withdrawing DDGS from the diet 0, 3, 6, and 9 weeks pre-harvest

- **Belly firmness**
  - D30-0 < control

- **Belly fatty acid composition**
  - **PUFA**
    - Increased with DDGS level
    - Decreased with DDGS withdrawal
    - Control = D15-9
  - **Iodine value**
    - Increased with DDGS level
    - Decreased with DDGS withdrawal
    - Control = D15-9 and D30-9
  - **Monounsaturated fatty acids**
    - Increased with DDGS level
  - **Saturated fatty acids**
    - Decreased with DDGS level
    - Increased with DDGS withdrawal
Effect of dietary DDGS level and withdrawal interval on belly firmness

DDGS withdrawal interval

D30-0 < control (P < 0.05)

PSE = 1.19

P-value
D = 0.99
W = 0.53
D × W = 0.20
Effect of dietary DDGS level and withdrawal interval on C18:2 content of belly fat

All treatments > control (P < 0.05)
Effect of dietary DDGS level and withdrawal interval on PUFA of belly fat

PSE = 0.74

P-value
D < 0.001
W < 0.001
D × W = 0.8

DDGS withdrawal interval

D15-9 wk = control, others > control (P < 0.01)
Effect of dietary DDGS level and withdrawal interval on IV of belly fat

PSE = 1.30

P-value
D < 0.001
W < 0.001
D × W = 0.3

DDGS withdrawal interval
D15-9 wk and D30-9 wk = control
All others > control (P < 0.05)
Summary of the effects of DDGS withdrawal interval pre-harvest

- C18:2 and IV of belly fat are linearly reduced over time when DDGS is removed or reduced in the diet.

- IV ≤ 70 can be achieved under the following feeding scenarios:
  - 15% dietary DDGS throughout the G-F period with no withdrawal.
  - 30% dietary DDGS with a 3 wk withdrawal interval pre-harvest.
Effects of feeding reduced oil and high oil corn co-products on pork fat quality

- Low solubles DDG (~8.8% fat DM basis)
- HP-DDGS (~3.4% fat DM basis)
- Corn germ (~19.1% fat DM basis)
- De-oiled DDGS (3-4%? DM basis)
Effect of Feeding 20% LS-DDG (8.8% Crude Fat DM basis) and 20% DDGS on Belly Fat Fatty Acid Profile

Amaral et al., 2009
Effect of Feeding 20% LS-DDG (8.8% Crude Fat DM basis) and 20% DDGS on Belly Fat Characteristics

Amaral et al., 2009
Linear decrease in belly firmness score from increasing DDGS levels (P < 0.02)
Linear decrease in belly firmness score from increasing HP-DDG levels (P < 0.06)
Linear increase in IV from increasing HP-DDG levels (P < 0.004)
Linear decrease in IV from increasing levels of corn germ (P < 0.001)
IV of DDGS > corn germ (P < 0.05)

Widmer et al., 2008
Effect of Feeding DDGS, HP-DDGS, Corn Germ on Bacon and Loin Quality Characteristics

- No effect of on:
  - cooking loss
  - shear force
  - bacon distortion score
  - overall palatability

Widmer et al., 2008
Linear decrease in carcass yield ($P < 0.01$)
Linear increase in jowl and belly fat IV ($P < 0.01$)

Jacela et al. (2008)
BASF has FDA approval for use in grower-finisher diets

Diet inclusion rate will likely be 1% (0.6% CLA) and be fed the last 10-30 days pre-harvest

\[ \text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}-\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH} \]

9,11-Conjugated Linoleic Acid
Conjugated linoleic acid (White et al., 2009)

- Fed 0, 20, or 40% DDGS diets during the final finishing phase
  - n = 36 pigs (12 pigs/treatment)

- Half of each group (n = 6) were fed 0.6% CLA during last 10 d pre-harvest
Conjugated linoleic acid (White et al., 2009)

- No differences in:
  - Loin eye area
  - 10th rib backfat depth
  - Last rib midline back fat depth
  - Loin color
  - Marbling
  - Firmness
  - Drip loss

- Increasing DDGS levels increased IV and n6:n3 fatty acids

- Adding 0.6% CLA decreased IV and ratio of n6:n3 fatty acids in 20% and 40% DDGS diets

- Increasing DDGS levels decreased bacon lean:fat ratio
Effect of Dietary Crude Glycerol Level on Carcass Characteristics

<table>
<thead>
<tr>
<th></th>
<th>0% Glycerol</th>
<th>5% Glycerol</th>
<th>10% Glycerol</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pigs</td>
<td>30</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>8.0</td>
<td>8.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>133</td>
<td>134</td>
<td>133</td>
</tr>
<tr>
<td>10th rib backfat, mm</td>
<td>18.8</td>
<td>21.0</td>
<td>20.7</td>
</tr>
<tr>
<td>LM area, cm²</td>
<td>48.6</td>
<td>49.0</td>
<td>46.6</td>
</tr>
<tr>
<td>Fat free lean, %</td>
<td>52.0</td>
<td>51.8</td>
<td>50.6</td>
</tr>
<tr>
<td>Lean gain, g/d</td>
<td>365</td>
<td>363</td>
<td>355</td>
</tr>
<tr>
<td>Carcass lean, %</td>
<td>55.7</td>
<td>54.7</td>
<td>55.7</td>
</tr>
</tbody>
</table>

No significant differences were observed among dietary treatments
Lammers et al., 2008
### Effect of LT and ST feeding of 8% crude glycerol diets on belly characteristics

<table>
<thead>
<tr>
<th></th>
<th>0% Glycerol</th>
<th>LT Glycerol</th>
<th>ST Glycerol</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of bellies</td>
<td>13</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Adjusted belly firmness, degrees</td>
<td>30.3</td>
<td>35.3</td>
<td>42.3</td>
</tr>
<tr>
<td>Belly thickness, cm</td>
<td>3.2</td>
<td>3.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Minolta L*</td>
<td>82.5</td>
<td>82.1</td>
<td>82.4</td>
</tr>
<tr>
<td>Minolta a*</td>
<td>6.6</td>
<td>6.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Minolta b*</td>
<td>6.0</td>
<td>5.7</td>
<td>5.6</td>
</tr>
</tbody>
</table>

Pigs fed ST Glycerol had firmer bellies vs. control (P < 0.05)  

Schieck et al., 2009
# Comparison of fatty acid composition of selected dietary fat sources

<table>
<thead>
<tr>
<th>Type of lipid</th>
<th>Total Unsaturated, %</th>
<th>Total Saturated, %</th>
<th>U:S ratio</th>
<th>Iodine Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef Tallow</td>
<td>47.9</td>
<td>52.1</td>
<td>0.92</td>
<td>44</td>
</tr>
<tr>
<td>Choice White Grease</td>
<td>59.2</td>
<td>40.8</td>
<td>1.45</td>
<td>60</td>
</tr>
<tr>
<td>Corn Oil</td>
<td>86.7</td>
<td>13.3</td>
<td>6.53</td>
<td>125</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>84.9</td>
<td>15.1</td>
<td>5.64</td>
<td>130</td>
</tr>
</tbody>
</table>
Effect of adding % tallow to 30% DDGS diets on belly flop angle

Pomerancke et al., 2010 (unpublished)
Carcass characteristics of pigs fed liquid diets containing corn and soybean meal with either non-fermented CDS at 15% dry matter (de Lange, 2006).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Non-fermented CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final body wt, kg</td>
<td>50.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carcass dressing, %</td>
<td>82.1</td>
<td>82.6</td>
</tr>
<tr>
<td>Backfat depth, mm</td>
<td>16.6</td>
<td>17.1</td>
</tr>
<tr>
<td>Loin depth, mm</td>
<td>54.3</td>
<td>53.7</td>
</tr>
<tr>
<td>Carcass lean yield, kg</td>
<td>61.1</td>
<td>60.9</td>
</tr>
<tr>
<td>Loin pH</td>
<td>5.74&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.80&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Loin drip loss, %</td>
<td>9.63</td>
<td>8.83</td>
</tr>
</tbody>
</table>

<sup>a, b</sup> Means within rows with different superscripts differ (P < 0.05).
Carcass characteristics of pigs fed liquid diets containing increasing levels of phytase treated steep water (SW; de Lange, 2006).

<table>
<thead>
<tr>
<th></th>
<th>0% SW</th>
<th>7.5% SW</th>
<th>15% SW</th>
<th>22.5 % SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pens</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Final body wt., kg</td>
<td>108.3</td>
<td>104.6</td>
<td>107.7</td>
<td>103.1</td>
</tr>
<tr>
<td>Carcass wt., kg</td>
<td>86.3</td>
<td>82.7</td>
<td>83.4</td>
<td>80.5</td>
</tr>
<tr>
<td>Loin depth, mm</td>
<td>58.2</td>
<td>58.9</td>
<td>56.4</td>
<td>58.3</td>
</tr>
<tr>
<td>Backfat depth, mm</td>
<td>18.1</td>
<td>18.7</td>
<td>18.0</td>
<td>17.1</td>
</tr>
<tr>
<td>Lean yield, %</td>
<td>60.3</td>
<td>60.3</td>
<td>60.5</td>
<td>60.1</td>
</tr>
</tbody>
</table>
Key Points

- Pork fat quality changes based on fatty acid composition of the diet
  - Dietary ingredients
    - Inclusion rates
    - Feeding period
    - Formulation strategies

- We can’t afford not to feed biofuels co-products
  - Availability of supply
  - Dietary cost savings
  - BUT we need to manage increased diversity and variable nutrient composition

- How should we define acceptable pork fat quality?
Does feeding oxidized fats affect pork fat quality and safety?
- Secondary oxidation products (HNE)
- What are the antioxidant levels and bioavailability of corn co-products?
- Should we be feeding higher levels of antioxidants (e.g. vitamin E)?

What is the digestibility of free fatty acids in fat sources?

What is the maximum level of methanol in crude glycerol that is safe?

What impact does feeding biofuels co-products have on omega fatty acids and cholesterol content of pork?

What are the long-term effects of feeding high levels of corn oil for choice white grease fatty acid profiles?

What are the long-term effects of feeding high levels of DDGS to sows on sausage quality?

Effects of Paylean and fat source and level?