Distiller’s Dried Grains with Solubles – Redefined for Swine

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University of Minnesota
What is DDGS?

- Co-product of the dry-milling ethanol industry
  - Corn (maize) DDGS - Midwestern US
  - Wheat DDGS - Canada
  - Sorghum (milo) DDGS - Great Plains US
  - Barley DDGS
  - Rye DDGS
Production of DDGS

- Yeasts and enzymes are used to ferment the starch fraction of corn
- Ethanol and carbon dioxide are produced
- Distiller’s grains and distiller’s solubles are the residues remaining after fermentation
- These fractions are blended and dried to produce distiller’s dried grains with solubles (DDGS)
Dry-Milling
Average Ethanol Yield Per Bushel (25.4 kg) of Corn

- Ethanol: 2.7 gallons (10.2 liters)
- DDGS: 18 lbs (8.2 kg)
- CO₂: 18 lbs (8.2 kg)

Slide courtesy of Ms. Kelly Davis, CVEC, Benson, MN
“New Generation” vs. “Old Generation” DDGS

Lower Quality,
Less Digestible
DDGS

High Quality,
Highly Digestible
DDGS
**Comparison of Energy Values for DDGS (88% Dry Matter Basis)**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DE, kcal/lb</td>
<td>1582</td>
<td>1600</td>
<td>1546</td>
<td>1564</td>
</tr>
<tr>
<td></td>
<td>Range 1550-1604</td>
<td>Range 1349-1853</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME, kcal/lb</td>
<td>1434</td>
<td>1527</td>
<td>1405</td>
<td>1212</td>
</tr>
<tr>
<td></td>
<td>Range 1400-1458</td>
<td>Range 1279-1776</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Corn (NRC, 1998): DE (kcal/lb) = 1580  
ME (kcal/lb) = 1534
Comparison of Amino Acid Composition of DDGS (88% dry matter basis)

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>“New” DDGS</th>
<th>“Old” DDGS</th>
<th>DDGS (NRC, 1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysine, %</td>
<td>0.75 (17.3)</td>
<td>0.47 (26.5)</td>
<td>0.59</td>
</tr>
<tr>
<td>Methionine, %</td>
<td>0.63 (13.6)</td>
<td>0.44 (4.5)</td>
<td>0.48</td>
</tr>
<tr>
<td>Threonine, %</td>
<td>0.99 (6.4)</td>
<td>0.86 (7.3)</td>
<td>0.89</td>
</tr>
<tr>
<td>Tryptophan, %</td>
<td>0.22 (6.7)</td>
<td>0.17 (19.8)</td>
<td>0.24</td>
</tr>
<tr>
<td>Valine, %</td>
<td>1.32 (7.2)</td>
<td>1.22 (2.3)</td>
<td>1.23</td>
</tr>
<tr>
<td>Arginine, %</td>
<td>1.06 (9.1)</td>
<td>0.81 (18.7)</td>
<td>1.07</td>
</tr>
<tr>
<td>Histidine, %</td>
<td>0.67 (7.8)</td>
<td>0.54 (15.2)</td>
<td>0.65</td>
</tr>
<tr>
<td>Leucine, %</td>
<td>3.12 (6.4)</td>
<td>2.61 (12.4)</td>
<td>2.43</td>
</tr>
<tr>
<td>Isoleucine, %</td>
<td>0.99 (8.7)</td>
<td>0.88 (9.1)</td>
<td>0.98</td>
</tr>
<tr>
<td>Phenylalanine, %</td>
<td>1.29 (6.6)</td>
<td>1.12 (8.1)</td>
<td>1.27</td>
</tr>
</tbody>
</table>

Values in ( ) are CV’s among plants
## Comparison of Apparent Ileal Digestible Amino Acid Composition of DDGS (88% dry matter basis)

<table>
<thead>
<tr>
<th></th>
<th>&quot;New&quot; DDGS</th>
<th>&quot;Old&quot; DDGS</th>
<th>DDGS (NRC, 1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysine, %</td>
<td>0.39</td>
<td>0.00</td>
<td>0.27</td>
</tr>
<tr>
<td>Methionine, %</td>
<td>0.28</td>
<td>0.21</td>
<td>0.34</td>
</tr>
<tr>
<td>Threonine, %</td>
<td>0.55</td>
<td>0.32</td>
<td>0.49</td>
</tr>
<tr>
<td>Tryptophan, %</td>
<td>0.13</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Valine, %</td>
<td>0.81</td>
<td>0.45</td>
<td>0.77</td>
</tr>
<tr>
<td>Arginine, %</td>
<td>0.79</td>
<td>0.53</td>
<td>0.77</td>
</tr>
<tr>
<td>Histidine, %</td>
<td>0.45</td>
<td>0.26</td>
<td>0.40</td>
</tr>
<tr>
<td>Leucine, %</td>
<td>2.26</td>
<td>1.62</td>
<td>1.85</td>
</tr>
<tr>
<td>Isoleucine, %</td>
<td>0.63</td>
<td>0.37</td>
<td>0.64</td>
</tr>
<tr>
<td>Phenylalanine, %</td>
<td>0.78</td>
<td>0.60</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Comparison of Phosphorus Level and Relative Availability of DDGS (88% dry matter basis)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total P, %</td>
<td>0.78</td>
<td>0.79</td>
<td>0.73</td>
<td>0.25</td>
</tr>
<tr>
<td>Range</td>
<td>0.62-0.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P Availability, %</td>
<td>90</td>
<td>No data</td>
<td>77</td>
<td>14</td>
</tr>
<tr>
<td>Range</td>
<td>88-92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Available P, %</td>
<td>0.70</td>
<td>No data</td>
<td>0.56</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Why is there so much interest in feeding DDGS to swine?

- “New Generation” DDGS is high in digestible nutrients
- Economical partial replacement for:
  - corn
  - soybean meal
  - dicalcium phosphate
- Increasing production and supply
- Unique properties
  - reduce P excretion in manure
  - increase litter size weaned/sow
  - gut health benefits?
Maximum Inclusion Rates of “New Generation” DDGS in Swine Diets
(Based Upon University of Minnesota Performance Trials)

- Nursery pigs (> 7 kg)
  - Up to 25%

- Grow-finish pigs
  - Up to 20% (higher levels may reduce pork fat quality)

- Gestating sows
  - Up to 50%

- Lactating sows
  - Up to 20%

Assumptions: no mycotoxins formulate on a digestible amino acid and available phosphorus basis
Feeding “New Generation DDGS to Sows”
Effect of Feeding a 50% DDGS Diet on Sow Weight Gain During Gestation (Reproductive Cycle 1)

(P > .22)
MSE 10.12
Effect of Feeding 0 or 50% DDGS Gestation Diets and 0 or 20% DDGS Lactation Diets on Pigs Weaned/Litter

Dietary treatment

a, b, x, y Different superscripts indicate significant difference (P < .10).
Effect of Dietary Treatment Combination on Sow Lactation ADFI

![Graph showing feed intake for different dietary treatments.]

- **Dietary Treatment**
  - Control/Control
  - Control/DDGS
  - DDGS/Control
  - DDGS/DDGS

- **Feed Intake, lb/day**
  - Cycle 1
  - Cycle 2

- **Note:** Different superscripts indicate significant difference (P < .10).
Feeding “New Generation” DDGS to Weaned Pigs
Materials and Methods – Nursery Experiments

- Experiment 1
  - Pigs weaned at 19.0 ± 0.3 d of age
  - Weighed 7.10 ± 0.07 kg
- Experiment 2
  - Pigs weaned at 16.9 ± 0.4 d of age
  - Weighed 5.26 ± 0.07 kg
- Pigs were fed a commercial pelleted diet (d 0 to 3 postweaning)
- Phase II (d 4-17) and Phase III (d 18 – 35) diets were formulated on a digestible amino acid basis.
  - Diets contained 0, 5, 10, 15, 20, or 25% DDGS
Effect of DDGS Level on Growth Rate (Experiment 1)

Means not sharing a common superscript letter are significantly different ($P < .05$)
Effect of DDGS Level on ADFI (Experiment 1)

**Experimental period**

**ADFI (g/d)**

- Phase 2
  - 0% DDGS
  - 5% DDGS
  - 10% DDGS
  - 15% DDGS
  - 20% DDGS
  - 25% DDGS

- Phase 3
  - 0% DDGS
  - 5% DDGS
  - 10% DDGS
  - 15% DDGS
  - 20% DDGS
  - 25% DDGS

SE = 46.9

SE = 82.6

Phase (P < .01)
Effect of DDGS Level on Gain/Feed (Experiment 1)

Experimental period

- Phase 2
- Phase 3

SE = 0.11
SE = 0.06

- 0% DDGS
- 5% DDGS
- 10% DDGS
- 15% DDGS
- 20% DDGS
- 25% DDGS

G/F
Effect of DDGS Level on Growth Rate (Experiment 2)

Linear effect of diet
\( (P = .09) \)

Phase 2
- 0% DDGS
- 5% DDGS
- 10% DDGS
- 15% DDGS
- 20% DDGS
- 25% DDGS

Phase 3

SE = 55.1
SE = 51.1

Phase (\( P < .01 \))
Effect of DDGS Level on Feed Intake (Experiment 2)

Means not sharing a common superscript letter are significantly different (P < .05)

Linear effect of diet (P = .05)

Phase x Diet (P = .02)
Effect of DDGS Level on Gain/Feed (Experiment 2)

Experimental period

G/F

Phase 2

Phase 3

SE = 0.13

SE = 0.03

0% DDGS
5% DDGS
10% DDGS
15% DDGS
20% DDGS
25% DDGS

Phase

(P = .06)
Effect of DDGS Level on Final BW (Experiment 2)

**Dietary treatment**

- 0% DDGS
- 5% DDGS
- 10% DDGS
- 15% DDGS
- 20% DDGS
- 25% DDGS

Body weight, kg

<table>
<thead>
<tr>
<th>Diet Level</th>
<th>Body Weight, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% DDGS</td>
<td>19.0</td>
</tr>
<tr>
<td>5% DDGS</td>
<td>19.5</td>
</tr>
<tr>
<td>10% DDGS</td>
<td>20.0</td>
</tr>
<tr>
<td>15% DDGS</td>
<td>20.5</td>
</tr>
<tr>
<td>20% DDGS</td>
<td>21.0</td>
</tr>
<tr>
<td>25% DDGS</td>
<td>21.5</td>
</tr>
</tbody>
</table>

SE = 1.3
Feeding “New Generation” DDGS to Grow-Finish Pigs
Fat Quality Characteristics of Market Pigs Fed Corn-Soy Diets Containing 0 to 30% DDGS

<table>
<thead>
<tr>
<th></th>
<th>0 %</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belly thickness, cm</td>
<td>3.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.00&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.84&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>2.71&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Belly firmness score, degrees</td>
<td>27.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.4&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>25.1&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>21.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Adjusted belly firmness score, degrees</td>
<td>25.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.8&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>25.4&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>22.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Iodine number</td>
<td>66.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>68.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>70.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>72.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means within a row lacking common superscripts differ (P < .05).
Formulation Methods for Diets Containing DDGS

- **Total vs digestible amino acid basis**
  - Maximum DDGS inclusion rate = 10%
    - if formulating on a total amino acid basis
  - Much higher DDGS inclusion rates (>10%)
    - if diets are formulated using digestible amino acids

- **Total vs available phosphorus basis**
  - Formulating diet on an available P basis increases economic benefit and reduces P content of manure
Cost Savings Depends on Diet Formulation Method Used
## Comparison of Formulating DDGS Diets on a Total Lysine and P Basis vs. Digestible Lysine and Available P Basis

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Typical Corn-SBM-Lysine Diet</th>
<th>10% DDGS Total Lysine</th>
<th>10% DDGS Digestible Lysine Available P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn, kg</td>
<td>731.5</td>
<td>650.5</td>
<td>643</td>
</tr>
<tr>
<td>Soybean meal 44%, kg</td>
<td>241</td>
<td>223</td>
<td>231.5</td>
</tr>
<tr>
<td>DDGS, kg</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Dicalcium phosphate, kg</td>
<td>12</td>
<td>9.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Limestone, kg</td>
<td>7</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Salt, kg</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>L-lysine HCl, kg</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>VTM premix, kg</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL, kg</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Total Cost, $</td>
<td>109.80</td>
<td>108.40</td>
<td>109.18</td>
</tr>
<tr>
<td>Difference, $</td>
<td>-</td>
<td>-1.40</td>
<td>-0.62</td>
</tr>
</tbody>
</table>

Corn = $2.00/bu, DDGS = $85/ton, soybean meal 44% = $190/ton, dicalcium phosphate = $15.00/cwt, limestone = $1.75/cwt, salt = $6.90/cwt, L-lysine HCl = $1.00/lb, VTM premix = $1.17/lb
Formulating on a total lysine and P basis replaces:

- 7.5 kg less corn ($0.079/kg)
- 8.5 kg more soybean meal 44% ($0.209/kg)
- 1 kg less dicalcium phosphate ($0.33/kg)

compared to formulating on a digestible amino acid and available phosphorus basis
Quick Calculation of Feed Cost Savings

Thumb rule:

Additions/2000 lbs diet

+ 200 lbs DDGS \( \times \) _____ $/lb = $_______
+ 3 lbs limestone \( \times \) _____ $/lb = $_______
TOTAL ADDITIONS (A) $_______

Subtractions/2000 lbs diet

- 177 lbs corn \( \times \) _____ $/lb = $_______
- 20 lbs SBM (44\%) \( \times \) _____ $/lb = $_______
- 6 lbs dical. phos. \( \times \) _____ $/lb = $_______
TOTAL SUBTRACTIONS (S) $_______

(S – A) = Feed cost savings/ton by adding 10% DDGS to the diet
Adding 20% DDGS to a corn-soy diet and formulating on an available P basis
- can reduce manure P by > 12%

Adding phytase to a corn-soy diet
- increases P bioavailability from 15% to > 45%

Lowering dietary P, adding 20% DDGS & phytase
- can reduce manure P excretion by 40 to 50%
## Diet Compositions and Cost Comparison from Adding 18.8% DDGS and Phytase

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Corn-SBM-1.5 kg Lysine</th>
<th>18.8% DDGS + Phytase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn, kg</td>
<td>798.3</td>
<td>636.3</td>
</tr>
<tr>
<td>Soybean meal 44%, kg</td>
<td>176.9</td>
<td>159.4</td>
</tr>
<tr>
<td>DDGS, kg</td>
<td>0.0</td>
<td>188</td>
</tr>
<tr>
<td>Dicalcium phosphate, kg</td>
<td>11.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Limestone, kg</td>
<td>7.2</td>
<td>9.8</td>
</tr>
<tr>
<td>Salt, kg</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>L-lysine HCl, kg</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>VTM premix, kg</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Phytase, 500 FTU/kg</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>TOTAL, kg</td>
<td>1000.0</td>
<td>1000.0</td>
</tr>
<tr>
<td>Total Cost, $</td>
<td>96.25</td>
<td>96.36</td>
</tr>
<tr>
<td>Difference, $</td>
<td>-</td>
<td>+ 0.11</td>
</tr>
</tbody>
</table>
Does Feeding DDGS Improve Gut Health?
DDGS and Gut Health

- Field reports:
  - Beneficial effect of adding 5 to 10% DDGS in grow-finish diets

- DDGS contains low levels of soluble (0.7 %) and high levels of insoluble (42.2 %) fiber (Shurson et al., 2000)
  - Low soluble fiber diets may reduce the proliferation of pathogenic organisms in the GI tract (Hampson, 1999).

- DDGS contains components of yeast cells
  - May have nutraceutical properties
What is Ileitis?

- Porcine Proliferative Enteropathy
- Caused by *Lawsonia intracellularis*
  - Present in 96% of U.S. swine herds (Bane et al., 1997)
    - 28% of pigs affected (NAHMS, 2000)
  - Can be shed in infected pigs for up to 10 weeks
- Animals are infected by oral contact with feces from animals shedding the bacteria
- 7-10 days after infection:
  - Lesions of the intestinal wall begin to form
  - Lesions maximized around 21 days post-infection
Porcine Intestinal Adenomatosis (PIA)
- Chronic form
- Seen in growing pigs (6 - 20 weeks of age)
- Decreased feed intake, lethargic

Porcine Hemorrhagic Enteropathy (PHE)
- Acute form, affects heavier pigs
  - Greatest frequency appears to be from 65 – 110 kg pigs
- Massive intestinal hemorrhaging, bloody diarrhea, increase in mortality
Effect of Dietary DDGS Level on Lesion Length (21 d Post-Challenge) Experiment 1

<table>
<thead>
<tr>
<th>Section of gastro-intestinal tract</th>
<th>NC</th>
<th>PC</th>
<th>D10</th>
<th>D20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jejunum*</td>
<td>a</td>
<td>b</td>
<td>a,b</td>
<td></td>
</tr>
<tr>
<td>Ileum*</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Cecum</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Colon</td>
<td></td>
<td></td>
<td>a</td>
<td>b</td>
</tr>
</tbody>
</table>

SE = 8.5 1.4 0.3 1.4

a,b Means not sharing a common superscript letter are different \((P < .05)\).

* Effect of disease challenge \((P < .05)\).
Effect of Dietary DDGS Level on Lesion Severity (21 d Post-Challenge) Experiment 1

a, b Means not sharing a common superscript letter are different (P < .05).
* Effect of disease challenge (P < .01).
Effect of Dietary DDGS Level on Lesion Prevalence (21 d Post-Challenge) Experiment 1

% of pigs

Section of gastro-intestinal tract

Jejunum* Ileum* Cecum Colon*

NC PC D10 D20

SE = 6.3 6.4 3.6 5.0

a, b Means not sharing a common superscript letter are different (P < .05).

* Effect of disease challenge (P < .01).
Effect of Dietary DDGS Level on Fecal Shedding (PCR Analysis)

Experiment 1

SE = 0.0

\[
\begin{array}{c}
\text{% of pigs} \\
\text{d 0} & \text{d 14*} & \text{d 21*} \\
\text{NC} & \text{PC} & \text{D10} & \text{D20} \\
\end{array}
\]

\(a, b\) Means not sharing a common superscript letter are different \((P < .05)\).

\* Effect of disease challenge \((P < .01)\).
Effect of DDGS Level on *L. intracellularis* Infection (IHC Analysis) Experiment 1

- **IHC Score**
  - SE = 0.12
  - Means not sharing a common superscript letter are different (*P* < .05).

- **IHC Prevalence**
  - SE = 2.8
  - Effect of disease challenge (*P* < .01).

*a,b* Means not sharing a common superscript letter are different (*P* < .05).

*Effect of disease challenge (*P* < .01).*
Summary of Results – Experiment 1

- DDGS inclusion did not improve the pig’s ability to resist an ileitis challenge
- Dosage (inoculation) rate was higher than desired
  - Actual: $1.56 \times 10^9$ dose of *L. intracellularis*
  - Goal: $1 \times 10^8$ dose of *L. intracellularis*
Effect of Dietary Treatment on Lesion Length (21 d Post-Challenge) Experiment 2

* Effect of disease challenge ($P < .01$).
Effect of Dietary Treatment on Lesion Severity (21 d Post-Challenge) Experiment 2

* Effect of disease challenge ($P < .01$).
Effect of Dietary Treatment on Lesion Prevalence (21 d Post-Challenge) Experiment 2

* Effect of disease challenge \((P < .01)\).
Effect of Dietary Treatment on Fecal Shedding (PCR Analysis) Experiment 2

* Effect of disease challenge ($P < .01$).
Effect of Treatment on *L. intracellularis* Infection (IHC Analysis) Experiment 2

**IHC Score**

- D10 ($P = .05$)
- AR ($P = .10$)

**SE = 0.12**

**IHC Prevalence**

- SE = 2.8

* Effect of disease challenge ($P < .01$).
Summary of Results, Experiment 2

- Inoculation level was closer to goal
- DDGS inclusion (10%) or antimicrobial regimen had a positive effect on the pig’s ability to resist an ileitis challenge
- No beneficial additive effects of combining DDGS and BMD®/Aureomycin® regimen
We have developed a DDGS web site featuring:

* research summaries
  - swine, poultry, dairy, & beef
  - DDGS quality
* presentations given
* links to other DDGS related web sites
* international audiences