Ethanol By-Products in Swine Feeding Programs

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Estimated DDGS Usage in U.S. Swine Feeds 2001-2005 (Metric Tonnes)
DDGS Varies in Nutrient Content and Digestibility, Color, and Particle Size Among U.S. Sources
Averages, Coefficients of Variation, and Ranges of Selected Nutrients Among 32 U.S. DDGS Sources (100% Dry Matter Basis)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>89.3</td>
<td>87.3 – 92.4</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>30.9 (4.7)</td>
<td>28.7 – 32.9</td>
</tr>
<tr>
<td>Crude fat, %</td>
<td>10.7 (16.4)</td>
<td>8.8 – 12.4</td>
</tr>
<tr>
<td>Crude fiber, %</td>
<td>7.2 (18.0)</td>
<td>5.4 – 10.4</td>
</tr>
<tr>
<td>Ash, %</td>
<td>6.0 (26.6)</td>
<td>3.0 – 9.8</td>
</tr>
<tr>
<td>Swine ME, kcal/kg</td>
<td>3810 (3.5)</td>
<td>3504 – 4048</td>
</tr>
<tr>
<td>Lysine, %</td>
<td>0.90 (11.4)</td>
<td>0.61 – 1.06</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.75 (19.4)</td>
<td>0.42 – 0.99</td>
</tr>
</tbody>
</table>
Comparison of Nutrient Composition of Golden Corn DDGS to Other “DDGS Sources” (100% Dry Matter Basis)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Golden Corn DDGS</th>
<th>Solulac</th>
<th>Badger State Ethanol</th>
<th>ADM - Peoria</th>
<th>Extruded DDGS/Soy (XDS Plus)</th>
<th>AGP Pelleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein, %</td>
<td>31.82</td>
<td>29.32</td>
<td>31.62</td>
<td>30.12</td>
<td>34.44</td>
<td>27.0</td>
</tr>
<tr>
<td>Fat, %</td>
<td>11.32</td>
<td>3.52</td>
<td>15.25</td>
<td>8.96</td>
<td>13.33</td>
<td>9.00</td>
</tr>
<tr>
<td>Crude fiber, %</td>
<td>6.25</td>
<td>7.90</td>
<td>No data</td>
<td>7.77</td>
<td>7.78</td>
<td>15.10</td>
</tr>
<tr>
<td>ADF, %</td>
<td>12.37</td>
<td>11.80</td>
<td>17.91</td>
<td>20.95</td>
<td>14.44</td>
<td>No data</td>
</tr>
<tr>
<td>Ash, %</td>
<td>6.93</td>
<td>5.29</td>
<td>4.58</td>
<td>7.30</td>
<td>5.56</td>
<td>4.28</td>
</tr>
<tr>
<td>DE, kcal/kg*</td>
<td>4053</td>
<td>3808</td>
<td>No data</td>
<td>3796</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>ME, kcal/kg*</td>
<td>3781</td>
<td>3577</td>
<td>No data</td>
<td>3560</td>
<td>3749</td>
<td>No data</td>
</tr>
<tr>
<td>Lys, %</td>
<td>0.92</td>
<td>0.61</td>
<td>0.90</td>
<td>0.83</td>
<td>1.67</td>
<td>No data</td>
</tr>
<tr>
<td>Met, %</td>
<td>0.62</td>
<td>0.54</td>
<td>0.54</td>
<td>0.66</td>
<td>0.61</td>
<td>No data</td>
</tr>
<tr>
<td>Thr, %</td>
<td>1.17</td>
<td>1.01</td>
<td>1.04</td>
<td>1.13</td>
<td>2.50</td>
<td>No data</td>
</tr>
<tr>
<td>Trp, %</td>
<td>0.25</td>
<td>0.18</td>
<td>0.23</td>
<td>0.25</td>
<td>0.39</td>
<td>No data</td>
</tr>
<tr>
<td>Ca, %</td>
<td>0.07</td>
<td>0.12</td>
<td>0.06</td>
<td>0.51</td>
<td>0.22</td>
<td>0.17</td>
</tr>
<tr>
<td>P, %</td>
<td>0.77</td>
<td>0.78</td>
<td>0.89</td>
<td>0.68</td>
<td>0.72</td>
<td>0.62</td>
</tr>
</tbody>
</table>

*Calculated energy values for swine
Variation in Particle Size Among DDGS Samples Representing 25 U.S. Ethanol Plants 2005
Variation in Bulk Density (Lbs/Cubic Ft.) Among DDGS Samples Representing 25 U.S. Ethanol Plants 1/05
Fig. 1. Regression of digestible lys (%) and color (L*, b*)

\[ R^2 = 0.71 \]

\[ R^2 = 0.74 \]

Source: Dr. Sally Noll (2003)
Standardized Ileal Lysine Digestibility Coefficients Among 10 “Golden” Corn DDGS Sources (Stein et al, 2005)
Factors That Affect Nutrient Variability in DDGS

- Variation in Raw Materials
  - Types of grains
  - Grain variety
  - Grain quality
    - Soil conditions
    - Fertilizer
    - Weather
    - Production and harvesting methods
  - Grain formula
Factors That Affect Nutrient Variability in DDGS

- Variation in Processing Factors
  - Grind Procedure
    - Fineness
    - Duration
  - Cooking
    - Amount of water
    - Amount of pre-malt
    - Temperature and time
    - Continuous or batch fermentation
    - Cooling time
  - Conversion
    - Type, quantity, and quality of malt
    - Fungal amylase
    - Time and temperature
  - Dilution of converted grains
    - Volume and gallon per bushel or grain bill
    - Quality and quantity of grain products
  - Fermentation
    - Yeast quality and quantity
    - Temperature
    - Time
    - Cooling
    - Agitation
    - Acidity and production control
Factors That Affect Nutrient Variability in DDGS

- Variation in Processing Factors
  - Distillation
    - Type: vacuum or atmospheric, continuous or batch
    - Direct or indirect heating
    - Change in volume during distillation
  - Processing
    - Type of screen: stationary, rotating, or vibratory
    - Use of centrifuges
    - Type of presses
  - Evaporators
    - Temperature
    - Number
  - Dryers
    - Time
    - Temperature
    - Type
  - Amount of syrup mixed with grain
Comparison of the Nutrient Content of Corn Distiller’s Grains and Corn Condensed Distiller’s Solubles

<table>
<thead>
<tr>
<th>DM, %</th>
<th>CP, %</th>
<th>Fat, %</th>
<th>CF, %</th>
<th>Ash, %</th>
<th>Ca, %</th>
<th>P, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>Solubles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An “Ideal” DDGS Quality Assurance Program for Ethanol Plants

- Monitor incoming corn for mycotoxins and reject positive loads
- Standardize the amount of solubles added to the grains fraction to produce DDGS
- Use minimal drying time and temperature to produce DDGS
  - Dryer temperatures range from 445°F to 1150°F
- Segregate poor quality DDGS from good quality DDGS when it is produced
  - Price different qualities accordingly
- Provide transparent and frequent nutrient profile information to customers on the DDGS being produced
- Specify the testing procedures used to determine nutrient content
- Become ISO 9000:2001 and HAACP certified
Some of the Nutrient Variability is Due to the Use of Different Approved Laboratory Testing Procedures
Comparison of AOAC Approved Moisture Testing Methods

- 130-135° C for 1 hour
- 100-105° C for 3 hours
- 100-105° C for 4 hours
- 60-70° C for 24 hours
## Variability of Laboratory Results from the Same DDGS Sample Sent to 5 Different Commercial Laboratories

<table>
<thead>
<tr>
<th></th>
<th>Moisture</th>
<th>Fat</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab 1</td>
<td>12.69</td>
<td>13.73</td>
<td>26.00</td>
</tr>
<tr>
<td>Lab 2</td>
<td>10.48</td>
<td>10.01</td>
<td>26.30</td>
</tr>
<tr>
<td>Lab 3</td>
<td>10.09</td>
<td>10.04</td>
<td>27.02</td>
</tr>
<tr>
<td>Lab 4</td>
<td>10.64</td>
<td>8.73</td>
<td>26.13</td>
</tr>
<tr>
<td>Lab 5</td>
<td>13.30</td>
<td>10.15</td>
<td>26.29</td>
</tr>
<tr>
<td>NIR</td>
<td>12.60</td>
<td>9.40</td>
<td>25.00</td>
</tr>
</tbody>
</table>
Physical Characteristics to Monitor

- Bulk density
- Particle size
- Hunter color scores
  - L*
  - a*
  - b*
- pH
Nutrients to Monitor

- Moisture
- Crude protein
- Crude fat
- Crude fiber
- ADF
- NDF
- Ash
- Swine DE, ME, NE (calculated)
- Starch
Minerals

- Calcium
- Phosphorus
- Sulfur
- Chloride
- Sodium
Amino acids

- Lysine
- Methionine
- Threonine
- Tryptophan
- Cystine
Mycotoxins

- Aflatoxins
  - B₁, B₂, G₁, G₂
- Deoxynivalenol (DON)
- Zearalenone
- Fumonisins
  - B₁, B₂, B₃
Crude Protein Monitoring
Big River Resources (100% DM Basis)
1/11/05 – 3/6/06

Crude Protein, %

%
Lysine Monitoring
Big River Resources (100% DM Basis)
1/11/05 – 3/6/06
Use of DDGS in Swine Diets
What Do We Know About DDGS Use in Swine Diets?

- Nutrient composition, digestibility, and physical characteristics vary among sources.
  - Energy \( \geq \) corn
  - Light, golden color appears to be a reasonable predictor of high lysine digestibility
  - Phosphorus digestibility is very high (\( \sim 90\% \))

- Economical partial replacement for
  - Corn
  - Soybean meal
  - Dicalcium phosphate

- Variability among DDGS sources > among soybean meal sources

- Maximum diet inclusion rates have been initially determined under specific diet formulation conditions.
What Do We Know About DDGS Use in Swine Diets?

- Appears to reduce gut health problems due to ileitis
- May increase litter size weaned when fed at high levels to sows
- Increases weight gain of pigs nursing sows fed DDGS
- ~1.4 million metric tons were fed to pigs in 2005
Maximum Dietary Inclusion Rates of DDGS in Swine Diets
(Based Upon University of Minnesota Research 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
Current Commercial Dietary DDGS Inclusion Rates and Estimated Usage

- Grow-finish diets ~85-90%
  - 10-20% dietary inclusion rates

- Sow diets ~5-10%
  - Gestation - up to 30% dietary inclusion
  - Lactation - 5-10% of the diet

- Late nursery starter diets < 5%
  - Added at 5-10% of the diet
Barriers for Increased DDGS Use in Swine Diets

- Variability in nutrient content and digestibility
- Low particle size and flowability problems
- Perceived risk of mycotoxins (sows)
- Ability to pellet DDGS diets
- Understanding and managing effects on pork fat quality
Barriers for Increased DDGS Use in Swine Diets

- Controversy over palatability and negative effects on feed intake at high dietary inclusion rates
- Fast, accurate, and inexpensive *in vitro* methods to estimate amino acid digestibility among sources
- Net energy values
- Need for research and education to avoid confusion over new types of DDGS
Unique, Value-Added Attributes of DDGS Have Been Identified

- Improvements in gut health related to *Lawsonia intracellularis*
- Increased litter size weaned when high levels are fed to sows
- Manure P concentration is reduced
The Value of New Distiller’s By-Products in Swine Diets
Comparison of Nutrient Content of Dakota Gold DDGS with High Protein Dakota Gold and Corn Protein Concentrate (100% DM Basis)
Comparison of Amino Acid Content of Dakota Gold DDGS with High Protein Dakota Gold and Corn Protein Concentrate (100% DM Basis)
Comparison of Mineral Content of Dakota Gold DDGS with High Protein Dakota Gold and Corn Protein Concentrate (100% DM Basis)
Opportunity Costs of High Protein Corn By-Products in Swine Diets

<table>
<thead>
<tr>
<th></th>
<th>DDGS Spec. 1</th>
<th>DDGS Spec. 2</th>
<th>HP DDGS</th>
<th>CPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swine</td>
<td>$80.00</td>
<td>$78.00</td>
<td>$51.00</td>
<td>$61.60</td>
</tr>
</tbody>
</table>
Key Points for Evaluating and Using DDGS and New Distiller’s By-Products in Swine Diets

- Remember the primary components that affect nutritional and economic value
  - Metabolizable energy
  - Level and digestibility of amino acids
  - Level and availability of P

- Minimize variability in nutrient content by limiting the number of DDGS sources used

- Question generic nutrient specification values provided by the supplier when formulating diets
Key Points for Evaluating and Using DDGS and New Distiller’s By-Products in Swine Diets

- Request current, complete nutrient profiles from source(s) being considered
  - www.ddgs.umn.edu

- Request evidence of mycotoxin screening procedures and quality control procedures from each source

- Although higher protein distiller’s by-products may initially appear to have higher value, they are:
  - generally lower in fat and P content
  - still have inferior protein quality
We have developed a DDGS web site featuring:

* nutrient profiles and photos of DDGS samples
* research summaries
  - swine, poultry, dairy, & beef
  - DDGS quality
* presentations given
* links to other DDGS related web sites
* international audiences