Influence of processing on nutritive value of coproducts from biofuel production

Virginia State Feed Association
Nutritional Management “Cow” College
Roanoke, Virginia
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Disclaimer:

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What is a Coproduct?

- Webster’s dictionary:
  - “co-”
    - Together with, as in “co-operation”; joint as in “co-owner”; equally as in “co-extensive”.
  - “product”
    - Something that is produced by nature or made by industry or art.
- [www.businessdictionary.com](http://www.businessdictionary.com):
  - “co-product”
    - “Product manufactured along with a different product, in a process in which both are required in the production of another product. In comparison, a by-product is usually an undesirable product.”
    - Viewed 2012-12-07 at: [http://www.businessdictionary.com/definition/coproduct.html](http://www.businessdictionary.com/definition/coproduct.html)

Biofuels have changed how we feed

- Starch based biofuels
  - Feed stock
    - Usually corn
    - Wheat, sorghum, barley
  - Coproducts
    - Ethanol
    - Distillers grains
    - Gluten feed
    - Gluten meal
    - Corn germ
    - Corn oils
    - CO₂
Biofuels have changed how we feed

- **Oil/fat based biofuels**
  - Feed stock
    - Vegetable/plant oils
    - Animal fats
  - Coproducts
    - Oil seed crop meals
    - Biodiesel
    - Glycerin

#### Products from biofuel production that can be used in animal feed:

<table>
<thead>
<tr>
<th>Biofuel Feedstock</th>
<th>Co-Products</th>
<th>Volume produced (Pounds per 100 pounds of feedstock)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethanol</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn, wet milled</td>
<td>Corn Gluten feed</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td>Corn Gluten meal</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Corn oil</td>
<td>2.9</td>
</tr>
<tr>
<td>Corn, dry grind</td>
<td>Dried Distillers Grains w/ soluble</td>
<td>30.5</td>
</tr>
<tr>
<td>Sugar</td>
<td>Sugar stalks</td>
<td>27.0</td>
</tr>
<tr>
<td><strong>Cellulose ethanol</strong></td>
<td>Lignin</td>
<td>27.0</td>
</tr>
<tr>
<td>Switchgrass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid poplar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forrest residue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural residue</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biodiesel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>Meal, 44 – 48% protein</td>
<td>80 - 82</td>
</tr>
<tr>
<td>Canola</td>
<td>Meal, 28 - 36% protein</td>
<td>60 - 62</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Meal, 28% protein</td>
<td>60 - 63</td>
</tr>
<tr>
<td>Mustard</td>
<td>Meal, 28 – 36% protein</td>
<td>60 - 62</td>
</tr>
<tr>
<td>Cotton</td>
<td>Meal, 41% protein</td>
<td>84 - 86</td>
</tr>
<tr>
<td></td>
<td>Crude glycerin</td>
<td>10</td>
</tr>
</tbody>
</table>

Focus on Distillers Grains

• Of all the coproducts listed, the production of ethanol has resulted in distillers grains products being by far the most abundant.

• Distillers grains production volume is similar to, and at times exceeds, soybean meal production volume in the United States.

Historical production of ethanol co-products (Renewable Fuels Association, 2011)
Ethanol production basics:

- Feed coproducts from both wet mill and dry grind facilities can be used in wet and dry forms.
  - Wet mill corn plants produce ethanol, starch, bran, germ, and gluten products.
  - Dry grind ethanol plants produce ethanol, distillers grains products, and $\text{CO}_2$.

- Cellulosic ethanol plants:
  - Will produce ethanol, a lignin residue product, and possibly a yeast protein product.

Coproducts from ethanol production

- Wet milling
  - Germ (whole, or oil removed)
  - Corn oil (often human food grade)
  - gluten meal (as a wet feed or dried)
  - gluten feed (as a wet feed or dried)

- Dry grind
  - DGS (DDGS-dried, MDGS (mid-moisture), WDGS-wet)
    - DG (dried, or wet feed)
    - Solubles (wet, condensed, or dry feed)
  - Corn Distillers Oil (removed from solubles post-fermentation; used for biodiesel or feed)
Distillers Grains Production

http://www.extension.iastate.edu/agdm/crops/outlook/dgsbalancesheet.pdf viewed 1-8-2013

Dry Grind Process
1/3 ethanol ** 1/3 CO₂ ** 1/3 DDGS

Corn → Ground → Cooked → Liqui-faction → Fermentation → Distillation → Ethanol

Distiller's Grains → Centrifuge → Thin Stillage evaporated to Condensed Solubles

DDGS

CO₂
Effects of processing:
Quality.................Safety

<table>
<thead>
<tr>
<th>Product Quality</th>
<th>Feed/Food Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Physical attributes</td>
<td>– Biological</td>
</tr>
<tr>
<td>• Moisture</td>
<td>• Bacteria, virus, mold, plant</td>
</tr>
<tr>
<td>• Micron size</td>
<td>– Chemical</td>
</tr>
<tr>
<td>• Color</td>
<td>• Heavy metals</td>
</tr>
<tr>
<td>• Texture</td>
<td>• Mycotoxins</td>
</tr>
<tr>
<td>• Odor</td>
<td>• Poisons</td>
</tr>
<tr>
<td>– Nutritional content</td>
<td>• Antibiotics</td>
</tr>
<tr>
<td>– Nutrient digestibility or availability</td>
<td>– Physical</td>
</tr>
<tr>
<td></td>
<td>• Metal, glass, other foreign materials</td>
</tr>
</tbody>
</table>

Step by step

• A look at each step of the dry grind ethanol process

• And consideration of how ethanol process management affects coproducts
Dry Grind Process
Step by step processing discussion

Incoming Corn
- Nutrient levels: protein, fat, & starch variation
- Contaminants: physical, biological, chemical
- Heat damaged corn: lowers available sugars

Grinding
- Micron size: enzymatic starch digestion--surface area; DDGS starch content
- Hammer mill management: particle size variation, metal particles

Jet Cooking
- Time & Temperature: starch breakdown, amino acid damage
- This step eliminated in many systems

Compounds Added
- Sulfuric acid: sulfur levels in distillers products
- Sodium salts: sodium levels in distillers products
- Urea, ammonia: yeast protein production

Enzymes Added
- Amylases: level of residual sugars
- Phytases: phosphorus availability for yeast growth and in DDGS
- Fiber digesting enzymes: fiber level

Yeast added
- 5 ton of yeast biomass formed in a 250,000 gallon fermenter
  - Saccharomyces cerevisiae
- Yeast nutrition: yeast contain 6 – 8% nitrogen & 1.4 – 2% phosphorus
- Yeast protein content of distillers grains
- MOS (yeast cell wall) content in distillers grains

*From Ethanol Producer Magazine, December 2012, p. 56.
Sodium

- Sodium concentrations*: 
  - Corn 0.02% 
  - DDGS 0.20%

- DCAD* (dietary cation-anion difference) 
  - Close-up dry cow diet sodium <0.1% 
  - Lactating cow diet sodium >0.2%

  *from 2012 Feedstuffs Ingredient Reference Issue

In distillers grains:

- Ethanol process uses process additives that may contribute sulfur.

- Sulfur content:* 
  - Corn .12 % 
  - DDGS .75%

- Dietary sulfur*: 
  - Close up dry cows <0.4% 
  - Lactating cows .20 to .25%

- Considerations: 
  - DCAD 
  - Polioencephalomalacia

*from 2012 Feedstuffs Ingredient Reference Issue

Sulfur

- Considerations:
  - DCAD
  - Polioencephalomalacia

*predicted sulfur level from corn
**example of sulfur level reported on lab analysis
Yeast content of Distillers Grains*

- What is effect of fermentation yeast on quality of distillers grains products?

  - “Amino acid composition of yeast is nutritionally more balanced than that of corn”
    

- Estimates that about 20% of the protein in DDGS is from yeast and 80% of the protein in DDGS is from corn.

*http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=266706

Dry Grind Process
Step by step processing discussion

- **Fermenter Additives**
  - Antibiotics: residue concerns
  - Chlorine products: chlorine levels in feed
  - Nitrogen (urea and/or ammonia) and phosphorus for yeast nutrition

- **Fermentation**
  - Unfermented starch -- (seen from 0% to as high as 10% in DDGS)
  - Residual sugars-- (very low to as high as 9%) darker color
  - Mulliard reaction in dryer-- (heat + sugars = lysine destruction)

- **Distillation**
  - Fermented mash is called “beer”
  - 14 to 16 % ethanol by volume
  - Distilled to about 180 proof (90% ethanol)
  - Last water is removed by millipore filtration to achieve nearly pure ethanol
  - Law requires ethanol to be ‘denatured’ before shipment (made unfit for drinking)
Dry Grind Process
Step by step processing discussion

Whole stillage separated
- Centrifuge separates wet grains from solubles
- Solubles are condensed by evaporation—CDS
- Distillers corn oil separated from the solubles

Wet grain & CDS combined
- Rate of re-combination can vary
- Nutrients vary in wet grains and condensed distillers solubles
- Results in variable nutrient content of DDGS or WDGS

Dryer
- Excess temperature: Maillard reaction
- Reduced total lysine
- Reduced digestibility of amino acids
- Burnt odor, dark chocolate color= rejected product in some markets

Corn Distillers Oil
- Biggest change to distillers grains in the last decade
- Corn oil removed from solubles by centrifuge
  - Uses: biodiesel and animal feed
- Driven by economics:
  - DDGS ---- $.12 to $.16 / pound
  - Corn Distillers Oil ---- $.30 to $.50 / pound
  - 100 million gallon ethanol plant:
    - ~3 mmpgy corn distillers oil; results in ~8% fat DDGS
    - ~6 mmpgy corn distillers oil; results in ~4.5% fat DDGS
- Challenge is evaluating energy content of the resulting distillers grains products.
Dry Grind Process with oil removal
1/3 Ethanol ** 1/3 CO₂ ** 1/3 DDGS and Corn Distillers Oil

Corn → Ground Cooked → Liqui-faction → Fermentation

Distiller’s Grains → Whole Stillage → Corn Distillers Oil

DDGS → Thin Stillage evaporated to Condensed Solubles

Nutrient Profile Comparison

Grains fraction compared to Solubles fraction*

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Grains Fraction</th>
<th>Solubles Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter, %</td>
<td>34.3</td>
<td>27.7</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>33.8</td>
<td>19.5</td>
</tr>
<tr>
<td>Crude fat, %</td>
<td>7.7</td>
<td>17.4</td>
</tr>
<tr>
<td>Crude fiber, %</td>
<td>9.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Ash, %</td>
<td>3.0</td>
<td>8.4</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.56</td>
<td>1.30</td>
</tr>
</tbody>
</table>

*Goihl, Knott, and Shurson: Random samples from 6 Minnesota ethanol plants taken over a three week period and tested at Iowa Testing Laboratories, Eagle Grove, Iowa. Mean values reported.

Ratio of recombination can result in variable analysis of the DDGS
Dry Grind Process
Step by step processing discussion

- Flat storage area design...first-in-first-out
- Time needed to reduce temperature
- Flowability issues for transporters and end-users

- Maintain product quality -- flowability
- Mold formation
- Overheating

- Ingredient storage
- Ration formulation
- Ration preparation

Process effect: Nutrient Profiles of other Distillers Grains
Products from various process methods

<table>
<thead>
<tr>
<th>Product</th>
<th>Dry Matter, %</th>
<th>Crude Protein, %</th>
<th>Crude Fat, %</th>
<th>Crude Fiber, %</th>
<th>Ash, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional CDDGS1</td>
<td>89.3</td>
<td>30.9</td>
<td>10.7</td>
<td>7.2</td>
<td>6.0</td>
</tr>
<tr>
<td>Branded HP DDGS</td>
<td>91.6</td>
<td>44.8</td>
<td>3.9</td>
<td>7.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Branded Bran</td>
<td>-</td>
<td>14.6</td>
<td>9.8</td>
<td>3.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Branded Corn Germ</td>
<td>93.2</td>
<td>16.9</td>
<td>18.9</td>
<td>5.5</td>
<td>5.8</td>
</tr>
<tr>
<td>DDDDD DDGS</td>
<td>-</td>
<td>49.3</td>
<td>3.9</td>
<td>6.8</td>
<td>3.2</td>
</tr>
<tr>
<td>XXXX DDGS</td>
<td>-</td>
<td>58.5</td>
<td>4.5</td>
<td>2.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Hi-Protein DDGS</td>
<td>-</td>
<td>35.0-37.0</td>
<td>4.0-6.0</td>
<td>4.0-6.0</td>
<td>-</td>
</tr>
<tr>
<td>branded DDGS</td>
<td>-</td>
<td>40.0-50.0</td>
<td>2.5-4.0</td>
<td>7.0-11.0</td>
<td>-</td>
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<tr>
<td>Branded Germ</td>
<td>97.0</td>
<td>17.5</td>
<td>45.0</td>
<td>6.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Branded Bran</td>
<td>90.0</td>
<td>9.5</td>
<td>2.0</td>
<td>16.6</td>
<td>1.0</td>
</tr>
<tr>
<td>XXXXX</td>
<td>90.0</td>
<td>45.0</td>
<td>3.3</td>
<td>3.8</td>
<td>4.0</td>
</tr>
<tr>
<td>YYYY</td>
<td>90.0</td>
<td>30.0</td>
<td>2.5</td>
<td>8.2</td>
<td>2.5</td>
</tr>
<tr>
<td>branded DDGS</td>
<td>-</td>
<td>35.0-37.0</td>
<td>6.5</td>
<td>-</td>
<td>3.8</td>
</tr>
<tr>
<td>De-Oiled DDGS</td>
<td>89.9</td>
<td>31.3</td>
<td>2.3</td>
<td>-</td>
<td>6.2</td>
</tr>
</tbody>
</table>

*Sources and Notes: "Average select nutrient content of 32 U.S. corn DDGS samples." (2005)
** All values are on dry matter basis
*** The symbol "-" denotes information unavailable
SOURCE: Company literature & presentations
One other factor to consider:

**Variability of Laboratory Methods:** Results (in %) of one DDGS sample split and sent to 6 laboratories. 

...Purina Animal Nutrition - data on file

<table>
<thead>
<tr>
<th></th>
<th>Moisture</th>
<th>Fat</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>12.69</td>
<td>13.73</td>
<td>26.00</td>
</tr>
<tr>
<td>Sample 2</td>
<td>10.48</td>
<td>10.01</td>
<td>26.30</td>
</tr>
<tr>
<td>Sample 3</td>
<td>10.09</td>
<td>10.04</td>
<td>27.02</td>
</tr>
<tr>
<td>Sample 4</td>
<td>10.64</td>
<td>8.73</td>
<td>26.13</td>
</tr>
<tr>
<td>Sample 5</td>
<td>13.30</td>
<td>10.15</td>
<td>26.29</td>
</tr>
<tr>
<td>Sample 6</td>
<td>12.60</td>
<td>9.40</td>
<td>25.00</td>
</tr>
</tbody>
</table>

**Final AFIA Committee Method Recommendations (April 2007)**

From project funded by AFIA, NCGA, and RFA

<table>
<thead>
<tr>
<th>Method Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFTA 2.2.2.5</td>
<td>Lab Dry Matter (105 °C / 3 hr)</td>
</tr>
<tr>
<td>*AOAC 990.03</td>
<td>Protein (Crude) in Animal Feed - Combustion</td>
</tr>
<tr>
<td>*AOAC 2001.11</td>
<td>Protein (Crude) in Animal Feed and Pet Food (Copper Catalyst)</td>
</tr>
<tr>
<td>AOAC 945.16</td>
<td>Oil in Cereal Adjuncts (Petroleum Ether)</td>
</tr>
<tr>
<td>AOAC 978.10</td>
<td>Fiber (Crude) in Animal Feed and Pet Food (F.G. Crucible)</td>
</tr>
</tbody>
</table>

*aMethods are statistically similar and either is acceptable for use on DDGS*
Read this sentence....

Richard and Robert purchased a Golden Retriever.

Now, read it out loud without pronouncing any “R’s”.

Questions

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Direct Ship Ingredients & Global Ingredient Trading
Purina Animal Nutrition, LLC
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