Influence of processing on nutritive value of coproducts from biofuel production

Virginia State Feed Association
Nutritional Management "Cow" College
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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 :
  - "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*

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**
    - **CO_2**

Biofuels have changed how we feed

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

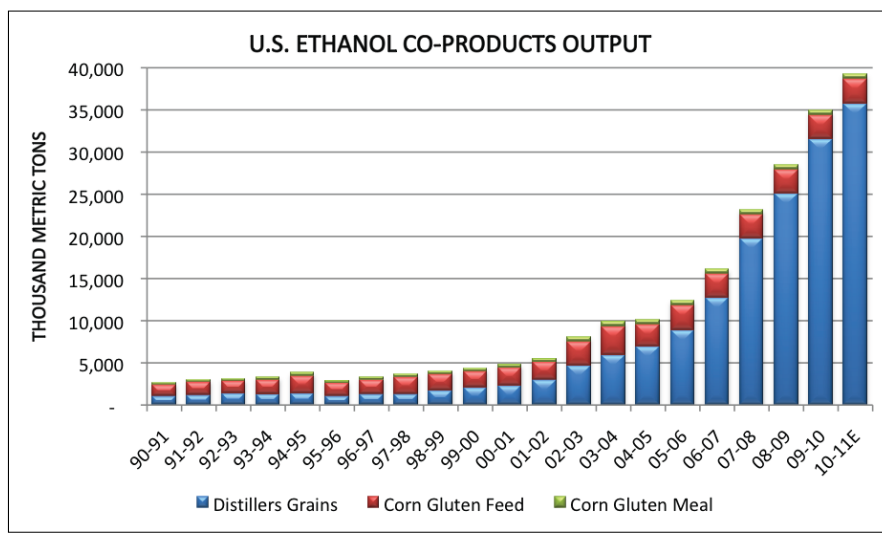
Products from biofuel production that can be used in animal feed:

Biofuel Feedstock	Co-Products	Volume produced *(Pounds per 100 pounds of feedstock)*
Ethanol		
Corn, wet milled	Corn Gluten feed	24.0
	Corn Gluten meal	4.5
	Corn oil	2.9
Corn, dry grind	Dried Distillers Grains w/ soluble	30.5
	Corn Distillers Oil	0 - 3
Sugar	Sugar stalks	27.0
Cellosic ethanol Switchgrass Hybrid popular Forrest residue Agricultural residue	Lignin	27.0
Biodiesel		
Soybeans	Meal, 44 – 48% protein	80 - 82
Canola	Meal, 28 - 36% protein	60 - 62
Sunflower	Meal, 28% protein	60 - 63
Mustard	Meal, 28 – 36% protein	60 - 62
Cotton	Meal, 41% protein	84 - 86
	Crude glycerin	10

http://www.eia.doe.gov/oiaf/analysispaper/pdf/tbl13.pdf viewed 2-15-2008

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:

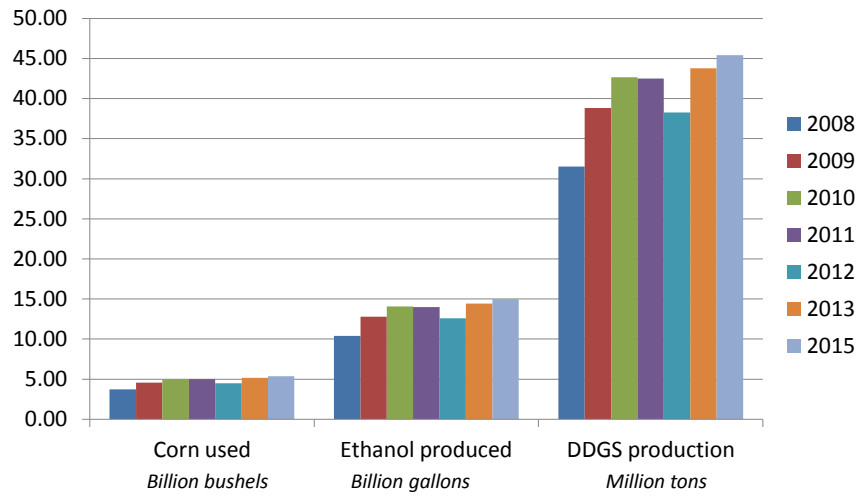
- Feed coproducts from both wet mill and dry grind facilities can be used in wet and dry forms.
  - Wet mill corn plants produce ethanol, starch, bran, germ, and gluten products.
  - Dry grind ethanol plants produce ethanol, distillers grains products, and CO_2 .
- Cellulosic ethanol plants :
  - Will produce ethanol, a lignin residue product, and possibly a yeast protein product.

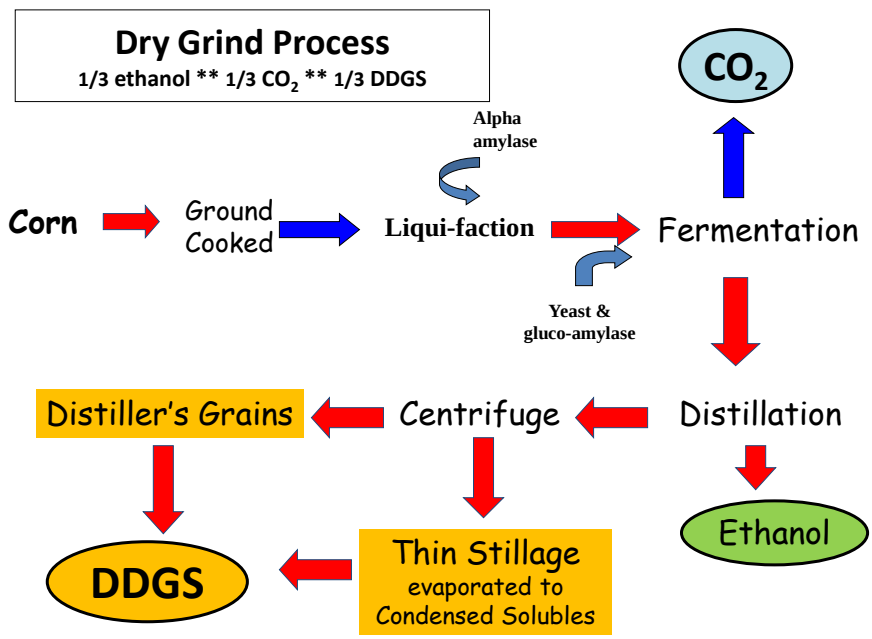
Coproducts from ethanol production

- 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*





Effects of processing: Quality……Safety

Product Quality

- **Physical attributes**
  - **Moisture**
  - **Micron size**
  - **Color**
  - **Texture**
  - **Odor**
- **Nutritional content**
- **Nutrient digestibility or availability**

Feed/Food Safety

- **Biological**
  - **Bacteria, virus, mold, plant**
- **Chemical**
  - **Heavy metals**
  - **Mycotoxins**
  - **Poisons**
  - **Antibiotics**
- **Physical**
  - **Metal, glass, other foreign materials**

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

Dry Grind Process

Step by step processing discussion

Compounds Added

- Sulfuric acid: sulfur levels is 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%

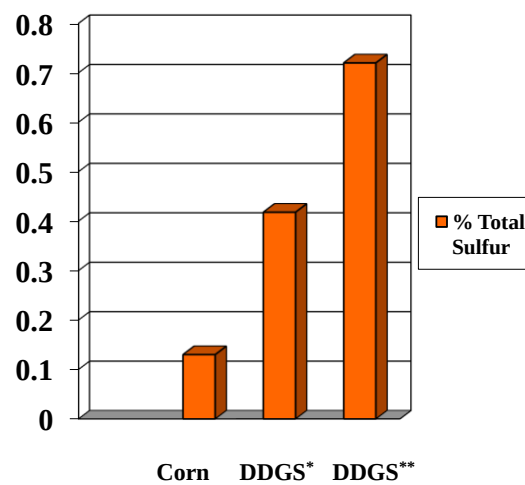
**from 2012 Feedstuffs Ingredient Reference Issue*

Sulfur

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*



**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"
    - *Han, J.C., Liu, K.S. 2011. Estimating the effect of fermentation yeast on distillers grains protein. INFORM, 22(4):244-247*
- 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

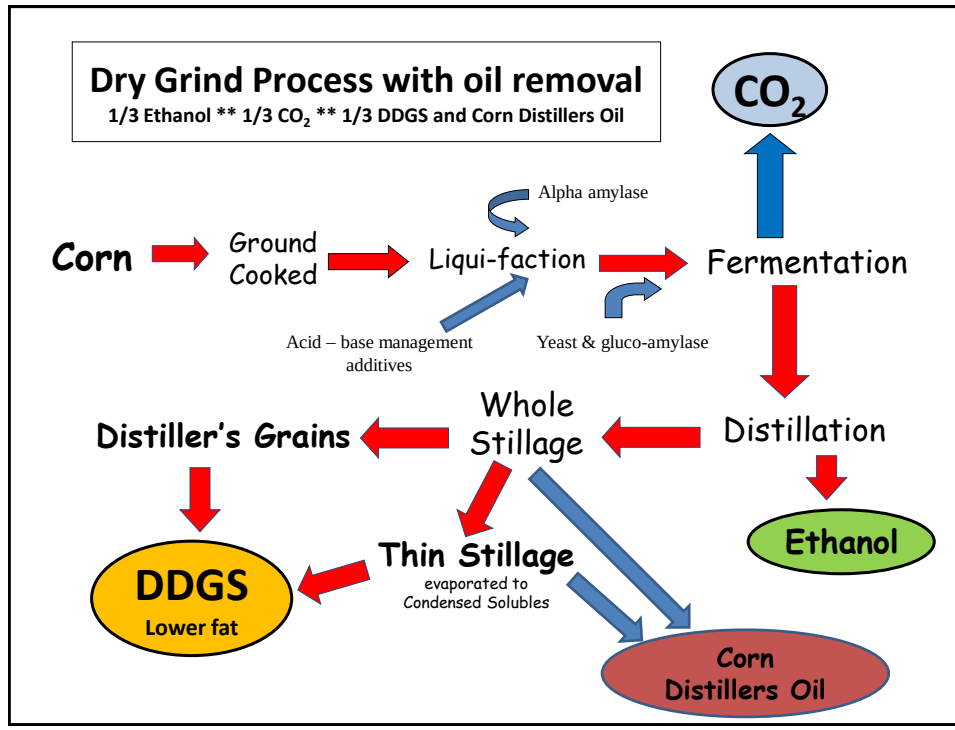
- Rate of re-combination can vary
- Nutrients vary in wet grains and condensed distillers solubles
- Results in variable nutrient content of DDGS or WDGS

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 mmgpy corn distillers oil ; results in ~8% fat DDGS
    - ~6 mmgpy corn distillers oil ; results in ~4.5% fat DDGS
- Challenge is evaluating energy content of the resulting distillers grains products.



Nutrient Profile Comparison

Grains fraction compared to Solubles fraction*

Nutrient	Grains Fraction	Solubles Fraction
Dry Matter, %	34.3	27.7
Crude protein, %	33.8	19.5
Crude fat, %	7.7	17.4
Crude fiber, %	9.1	1.4
Ash, %	3.0	8.4
Calcium, %	0.04	0.09
Phosphorus, %	0.56	1.30

*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

Cooling

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

Transport

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

End user

- Ingredient storage
- Ration formulation
- Ration preparation

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

Product	Dry Matter, %	Crude Protein, %	Crude Fat, %	Crude Fiber, %	Ash, %
Conventional CDDGS[1]	89.3	30.9	10.7	7.2	6.0
Branded HP DDGS	91.6	44.8	3.9	7.3	2.1
Branded Bran	-	14.6	9.8	3.8	4.6
Branded Corn Germ	93.2	16.9	18.9	5.5	5.8
DDDD DDGS	-	49.3	3.9	6.8	3.2
XXXX DDGS	-	58.5	4.5	2.0	3.2
Hi-Protein DDGS	-	35.0-37.0	4.0-6.0	4.0-6.0	-
branded DDGS	-	40.0-50.0	2.5-4.0	7.0-11.0	-
Branded Germ	97.0	17.5	45.0	6.0	1.9
Branded Bran	90.0	9.5	2.0	16.6	1.0
XXXXX	90.0	45.0	3.3	3.8	4.0
YYYYY	90.0	30.0	2.5	8.2	2.5
branded DDGS	-	35.0-37.0	6.5	-	3.8
De-Oiled DDGS	89.9	31.3	2.3	-	6.2

[1]Shurson and Noll. "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

	Moisture	Fat	Protein
Sample 1	12.69	13.73	26.00
Sample 2	10.48	10.01	26.30
Sample 3	10.09	10.04	27.02
Sample 4	10.64	8.73	26.13
Sample 5	13.30	10.15	26.29
Sample 6	12.60	9.40	25.00

Final AFIA Committee Method Recommendations (April 2007)

From project funded by AFIA, NCGA, and RFA

Moisture/Loss on Drying	
NFTA 2.2.2.5	**Lab Dry Matter (105 ºC / 3 hr)**
Crude Protein	
[a]AOAC 990.03	**Protein (Crude) in Animal Feed - Combustion**
[a]AOAC 2001.11	**Protein (Crude) in Animal Feed and Pet Food (Copper Catalyst)**
Crude Fat	
AOAC 945.16	**Oil in Cereal Adjuncts (Petroleum Ether)**
Crude Fiber	
AOAC 978.10	**Fiber (Crude) in Animal Feed and Pet Food (F.G. Crucible)**
[a]Methods 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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