

# Ethanol Processing Coproducts

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## Economics, Impacts, Sustainability

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# Introduction

- Energy needs
  - Continue to escalate
    - Increasing demand for energy
      - Non-renewable fossil fuels
- Biofuels
  - Can help meet these increasing needs
  - Renewable from biomass
    - Leading biofuel is ethanol
      - Straw, stover, grasses, legumes, woods, other organic/biological residues & wastes
  - Currently
    - Corn grain is most heavily utilized substrate



# Introduction

- Concern over inputs & outputs
  - Resource balance
  - Material balance
  - Energy balance
- Has become a focal point
  - Many public discussions
  - “Does ethanol pay???”
- Each manufacturing facility
  - Must contribute to the mission of sustainability
    - Coproducts/residues/residuals/byproducts/wastes
    - Are critical to this endeavor

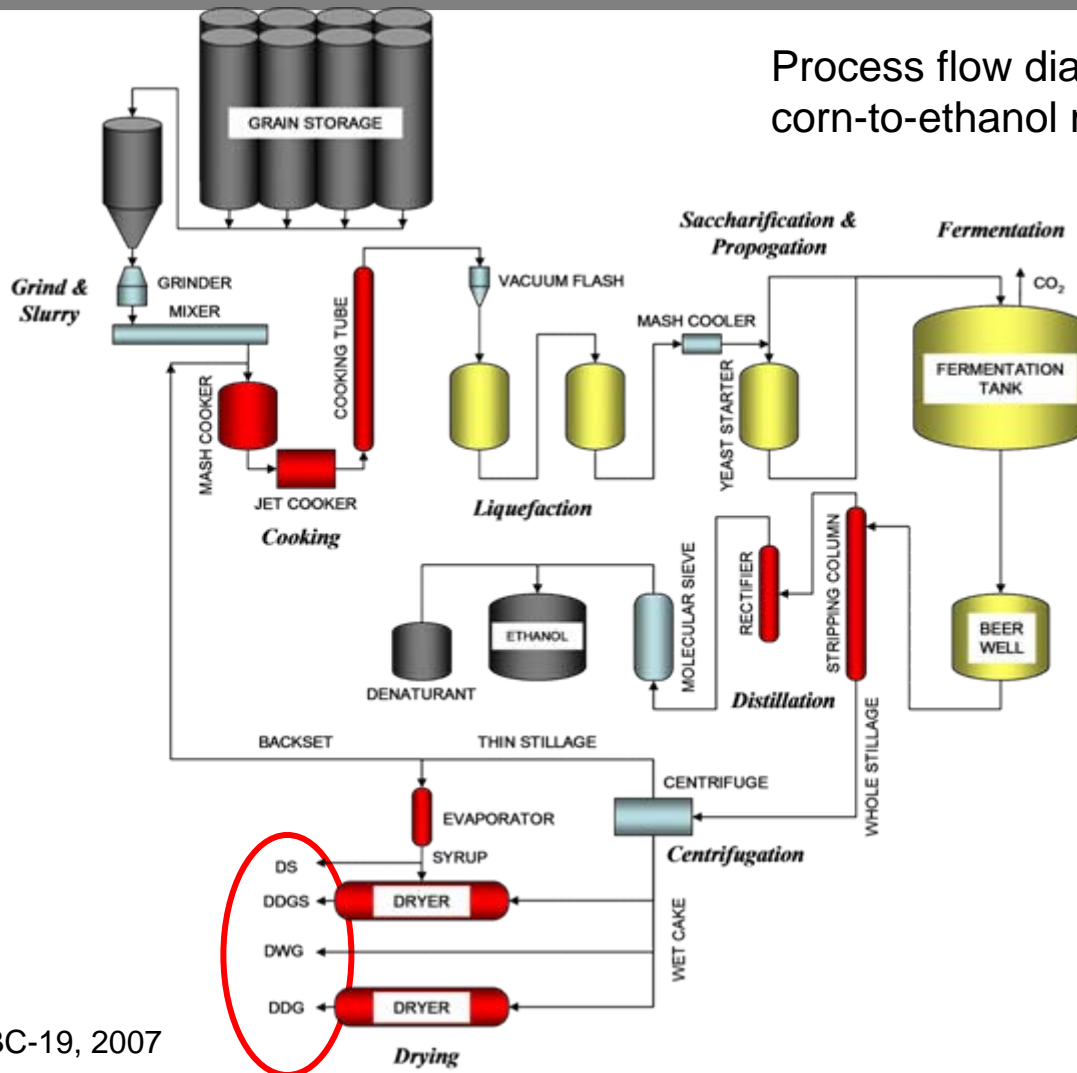


# Today's Outline

- 1) Ethanol manufacturing – process & coproducts
- 2) Current trends
- 3) Coproduct utilization
- 4) What are the industry's needs?
- 5) Addressing these issues
- 6) Implications & future directions

# Ethanol Manufacturing Process

Process flow diagram of a typical dry-grind corn-to-ethanol manufacturing process

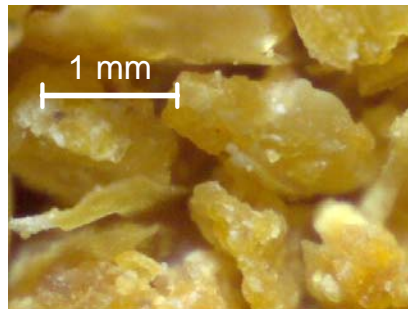
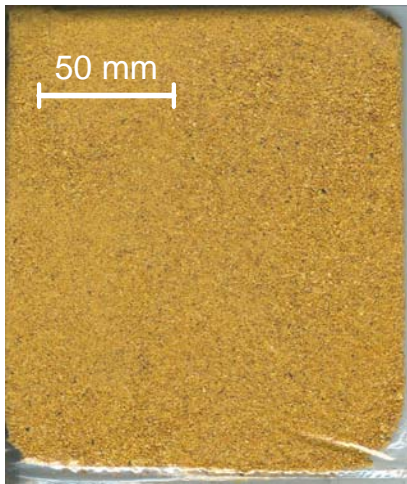


## Dry Mill Coproducts

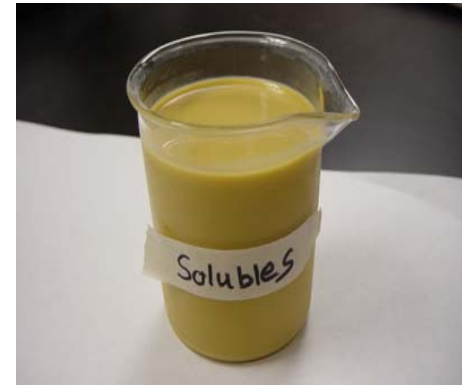
- DS: Distillers Solubles
- DDGS: Distillers Dried Grains with Solubles
- DWG: Distillers Wet Grains
- DDG: Distillers Dried Grains

# Ethanol Coproducts

Distillers Dried Grains with Solubles



Consensed Distillers Solubles



Distillers Wet Grains



# Ethanol Coproducts

- Dry grind manufacturing
  - 3 main products
    - Primary: ethanol
    - Secondary: CO<sub>2</sub> & non-fermentable components
  - Anecdotally
    - 1 kg corn = 1/3 kg ethanol + 1/3 kg CO<sub>2</sub> + 1/3 kg DDGS



- Actuality: broad range of conversion rates
  - 1 kg corn = 0.37 – 0.42 L ethanol
  - 1 kg corn = 0.282 – 0.323 kg DDGS
  - 1 kg corn = 0.287 – 0.329 kg CO<sub>2</sub>

*Depends on each facility's operations*

Dien et al. (2003), Kelsall & Lyons (2003), Kim & Dale (2002), Lyons (2003), Shapouri et al. (1995), Tibelius (1996)

# Ethanol Coproducts

## Chemical properties of corn distillers dried grains with solubles (DDGS) (% , d.b.)

## Chemical properties of corn distillers dried grains (DDG) (% , d.b.)

Property	Reported Values
Dry Matter	86.2 – 93.0
Protein	26.8 – 33.7
Amino Acids	
Alanine	1.8
Arginine	0.9 – 2.2
Aspartic Acid	1.8
Cystine	0.4 – 0.8
Glutamic Acid	4.6
Glycine	1.0
Histidine	0.6 – 1.0
Hydroxyproline	0.2
Isoleucine	0.9 – 1.5
Leucine	2.4 – 4.0
Lysine	0.5 – 1.1
Methionine	0.5 – 0.8
Phenylalanine	1.3 – 1.7
Proline	2.6
Serine	1.4
Threonine	0.8 – 1.3
Tryptophan	0.2 – 0.3
Tyrosine	0.8 – 1.0
Valine	1.3 – 1.8
Fat	3.5 – 12.8
Carbohydrates	39.2 – 61.9
Nitrogen Free Extract	33.8 – 54.0
Starch	4.7 – 5.9
Total Dietary Fiber	24.2 – 39.8
Crude Fiber	5.4 – 10.6
Neutral Detergent Fiber (NDF)	25.0 – 51.3
Acid Detergent Fiber (ADF)	8.0 – 21.0
Ash	2.0 – 9.8
Ca	0 – 0.5
P	0.4 – 1.0
K	0.5 – 1.3
Mg	0.1 – 0.4
S	0.3 – 1.1
Na	0 – 0.5
Cl	0.1 – 0.4
Zn (ppm)	38.0 – 312.1
Mn (ppm)	9.0 – 49.5
Cu (ppm)	3.0 – 13.5
Fe (ppm)	68.0 – 295.0

Property	Reported Values
Dry Matter	85.8 – 93.0
Protein	27.0 – 29.2
Fat	7.6 – 14.0
Total Carbohydrate	46.5
Crude Fiber	12.8
Neutral Detergent Fiber (NDF)	31.5 – 47.3
NDF Phenolics	4.9
Acid Detergent Fiber (ADF)	16.3 – 28.3
Acid Detergent Lignin (ADL)	11.1
Hemicellulose (NDF-ADF)	19.0
Cellulose (ADF-ADL)	17.2
Nonfiber Carbohydrate	9.8
Glucose	22.8
Xylose	8.9
Arabinose	6.3
Galactose	3.0
Mannose	2.6
Uronic Acids	3.0
ND-Soluble Uronic Acids	1.3
ND-Soluble Glucans	9.3
Ash	2.0

Rule of Thumb:  
Corn nutrients x 3

# Ethanol Coproducts

- Why should we care about
  - Protein, fiber, fat components?
- Presence/absence & quantities available
  - Dictate material behavior
    - Storability/stability
    - Material handling
  - Affect utilization options
    - Livestock feed
    - Other uses

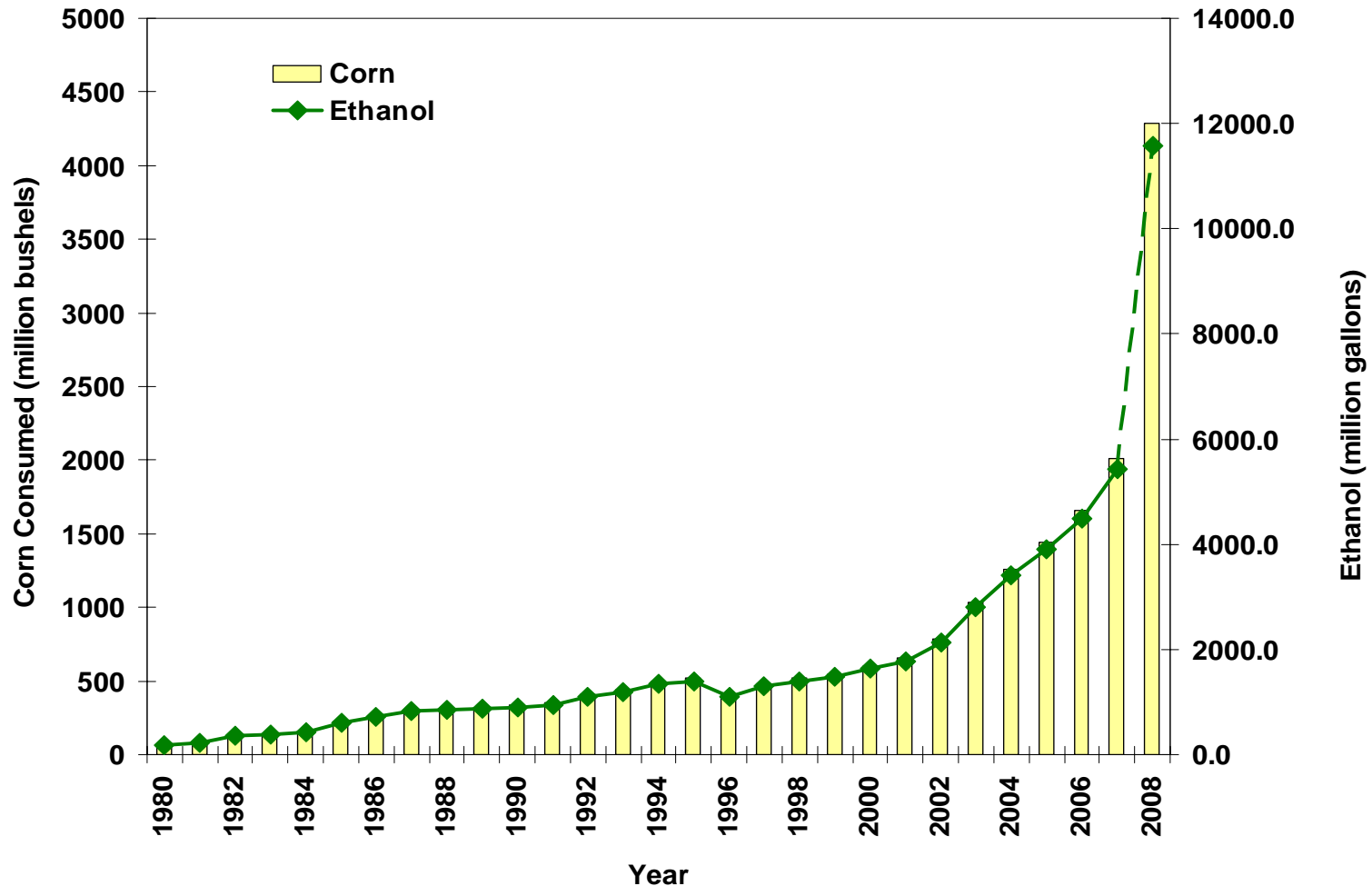
# Ethanol – A Growing Player

- US fuel ethanol industry
    - Rapid growth in recent years
      - 2007
        - Current capacity: 115 plants, 5.8 bgal/yr
        - 86 under construction/expansion: 6.3 bgal/yr
        - Total capacity: 12.1 bgal/yr
- US Energy Bill/RFS: 7.5 bgal/yr by 2012
- As ethanol production capacity grows
    - So too does growth in manufacturing coproducts
      - Dry grind plants
        - Distillers Dried Grains with Solubles (DDGS)

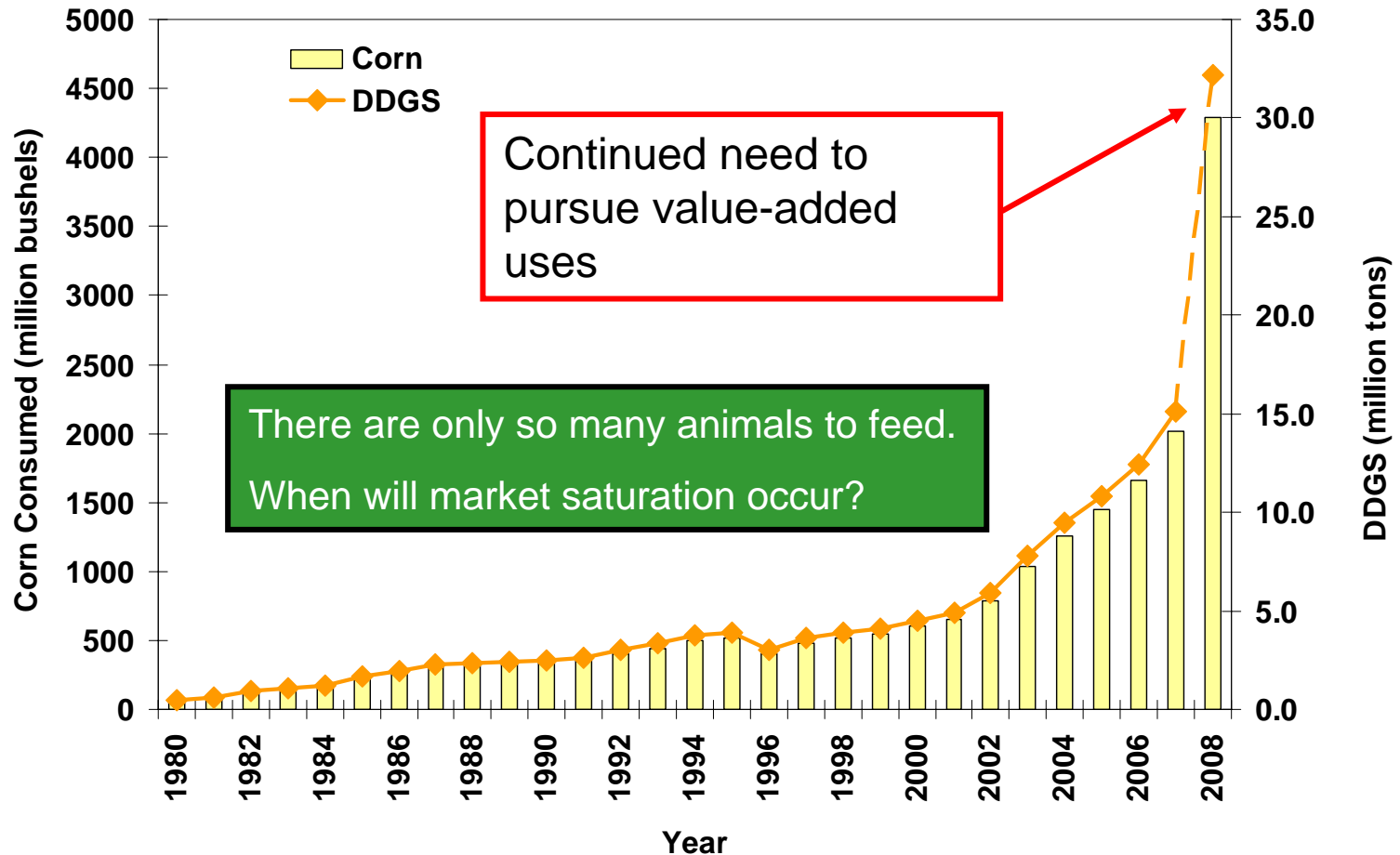
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# Trends in Ethanol Production



# Trends in Ethanol Production

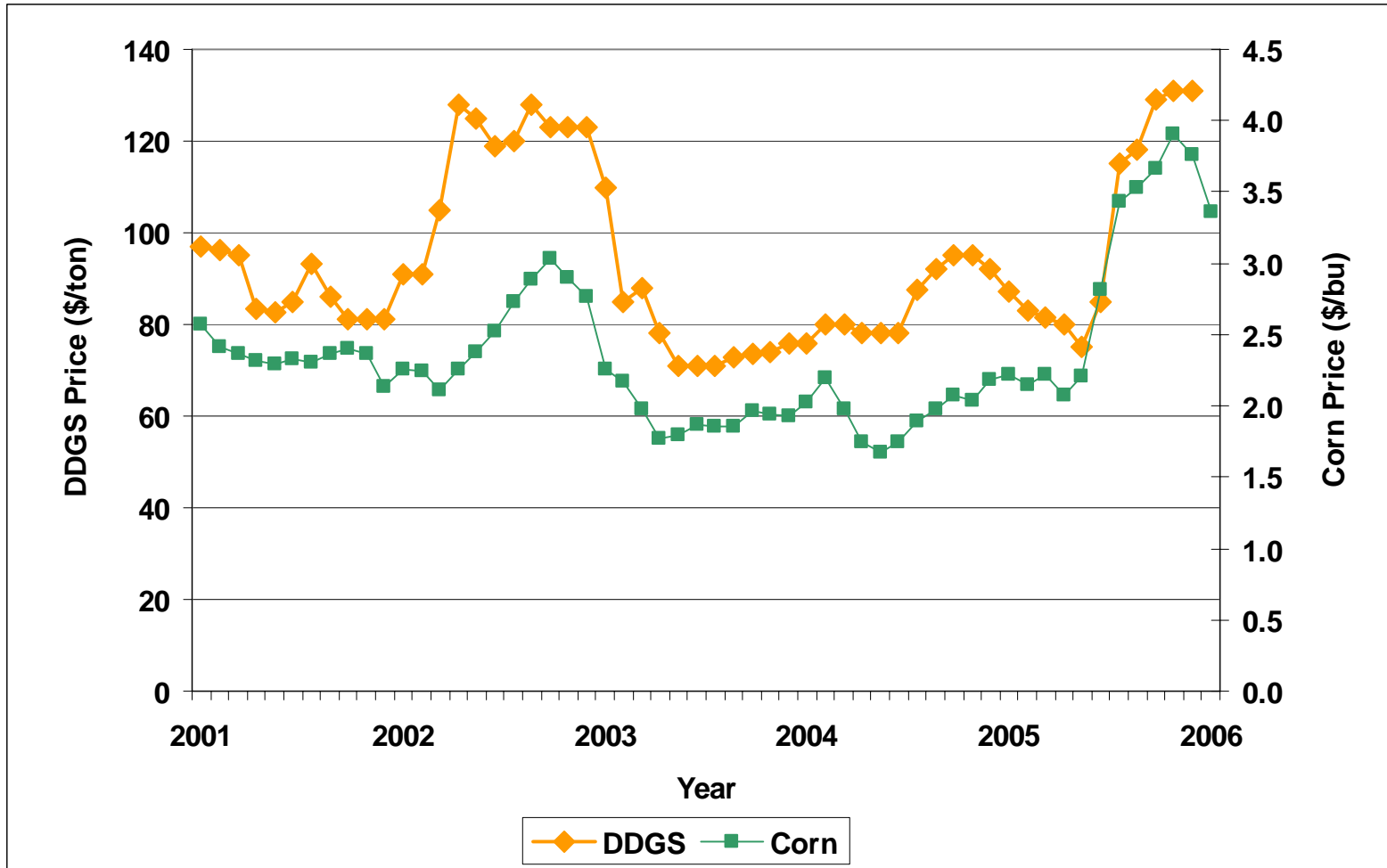


# Coproduct Utilization

Per 1 ton of DDGS		
Value of DDGS (\$/ton DDGS)	Value to Ethanol (\$/gal ethanol)	Value to Ethanol (\$/L ethanol)
80	0.27	0.062
100	0.33	0.078
120	0.40	0.093

- Sales of coproducts
  - Substantial revenue source for ethanol processors
  - Vital to plant profitability
- As the industry continues to expand
  - How will marketplace handle increasing demand for corn?
  - How will marketplace handle increasing supply of DDGS?

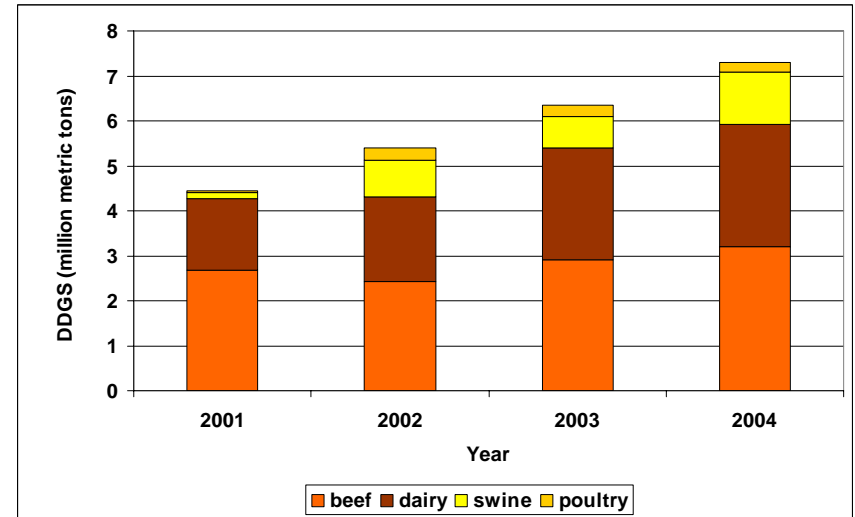
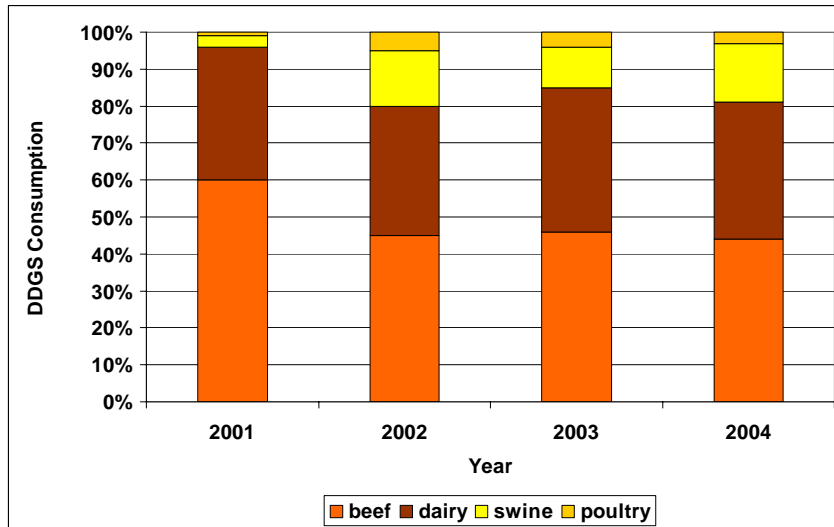
# Coproduct Utilization



# Coproduct Utilization

- Currently
  - Primary outlet for nonfermentable residues (coproducts)
    - **DDGS**
    - Others
      - DDG, WDG, WDGS, CDS, etc.
    - Livestock feeds
      - Dairy, beef, swine, poultry
      - Excellent feed ingredients
      - Numerous research studies (UMN, 2007)
  - We know how to feed DDGS to animals

# Coproduct Utilization



# Coproduct Utilization

- How much can be used as livestock feed in the U.S.?
  - Maximum level of utilization is a key question
    - Several estimates
      - Lower inclusion limits [100% market utilization]
        - » ~ 13.7 million tons (Cooper, 2006)
      - Upper inclusion limits [100% market utilization]
        - » ~ 40.3 million tons (Cooper, 2006)
        - » ~ 60 million tons (Staff, 2005)
- Long-term sustainability of the industry
  - Two thrusts are key
    - Marketing to livestock producers
    - Need to pursue other value-added alternatives for DDGS
      - Diversified utilization portfolio
- Thus, to achieve these, we must be cognizant of
  - Challenges & barriers
  - Opportunities

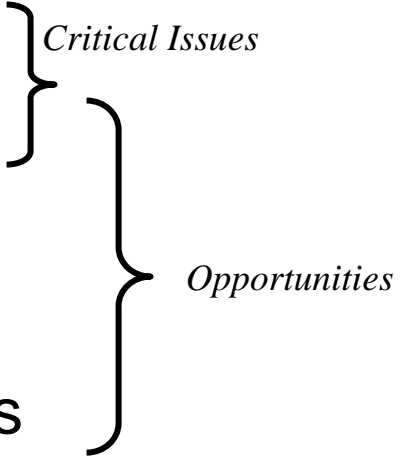
# Research Priorities – Top 10

- 1) Augmenting use in species-specific livestock markets
- 2) Improving nutritional content, quality, and value
- 3) Optimizing and maximizing inclusion rates
- 4) Developing livestock feeds with higher value
- 5) Utilizing next generation coproducts from new ethanol processes
- 6) Standardizing analytical laboratory methods
- 7) Educational activities for livestock producers
- 8) Transportation issues
- 9) Fractionating nutrients into concentrated streams
- 10) Environmental issues

# Addressing These Issues

- Very dynamic industry
  - Many research programs currently addressing these issues
    - Ethanol processors
    - Private enterprise
    - Commodity groups
    - Universities
    - Government agencies

# Addressing These Issues

- DDG Consortium
    - South Dakota State University
    - USDA-ARS
    - Private companies
  - 5 main thrusts
    - Storage, transportation, flowability
    - Animal feeding
    - Human foods
    - Industrial products
    - Next-generation DDGS - modifications
- 
- The diagram consists of two large curly brackets on the right side of the slide. The top bracket, labeled 'Critical Issues', encompasses the first three items of the '5 main thrusts' list: 'Storage, transportation, flowability', 'Animal feeding', and 'Human foods'. The bottom bracket, labeled 'Opportunities', encompasses the remaining two items: 'Industrial products' and 'Next-generation DDGS - modifications'.

# DDGS – Critical Issues

- Storage, transportation, flowability
  - Inter-particle bridging & caking
    - Rail cars & storage structures do not unload (~ 5-10% of all cars)
- Animal feeding
  - Optimize/maximize inclusion in livestock diets
    - Convert DDGS into higher-value feeds
      - Aquaculture feeds & pet foods
- Human foods
  - High protein, high fiber – potential for diabetic & Celiac markets
  - Taste, appearance, functionality
- Industrial products
  - Biofiller – plastic composites,



# DDGS – Opportunities

- Tremendous industry growth
- Changes in coproduct streams
  - Fractionation prior to fermentation
  - Fractionation after fermentation
  - Smaller plants may never change
- Modifying coproduct streams
  - Will necessitate changes in utilization
    - Feed vs. other uses (value-added applications)
    - New market opportunities

# DDGS – Opportunities

- Opportunities
  - Biorefinining
    - Lignocellulose/DDGS fiber conversion into ethanol
    - Corn/DDGS oil conversion into biodiesel
    - Value-added chemicals
    - Will all the coproducts be used as refinery feedstocks?
    - New coproduct/byproduct streams

- Chemical constituents

- Protein
- Fiber
- Fat

*How much is present?*

*What is resulting functionality?*

Answers to these questions will have a tremendous impact on all aspects of utilization

# Implications & Future Directions

- Achieving these objectives
  - Also addressing other challenges & constraints
  - Will be key as DDGS evolves
    - Dynamic industry
      - “Next generation” products
        - » Fractionation
        - » Enzymes/fermentation technology
        - » Novel process modifications
    - Impact coproduct generation & properties
      - Alter utilization opportunities
      - Coproduct utilization is key to success

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