# Ethanol Processing Coproducts

## Current Constraints & Future Directions


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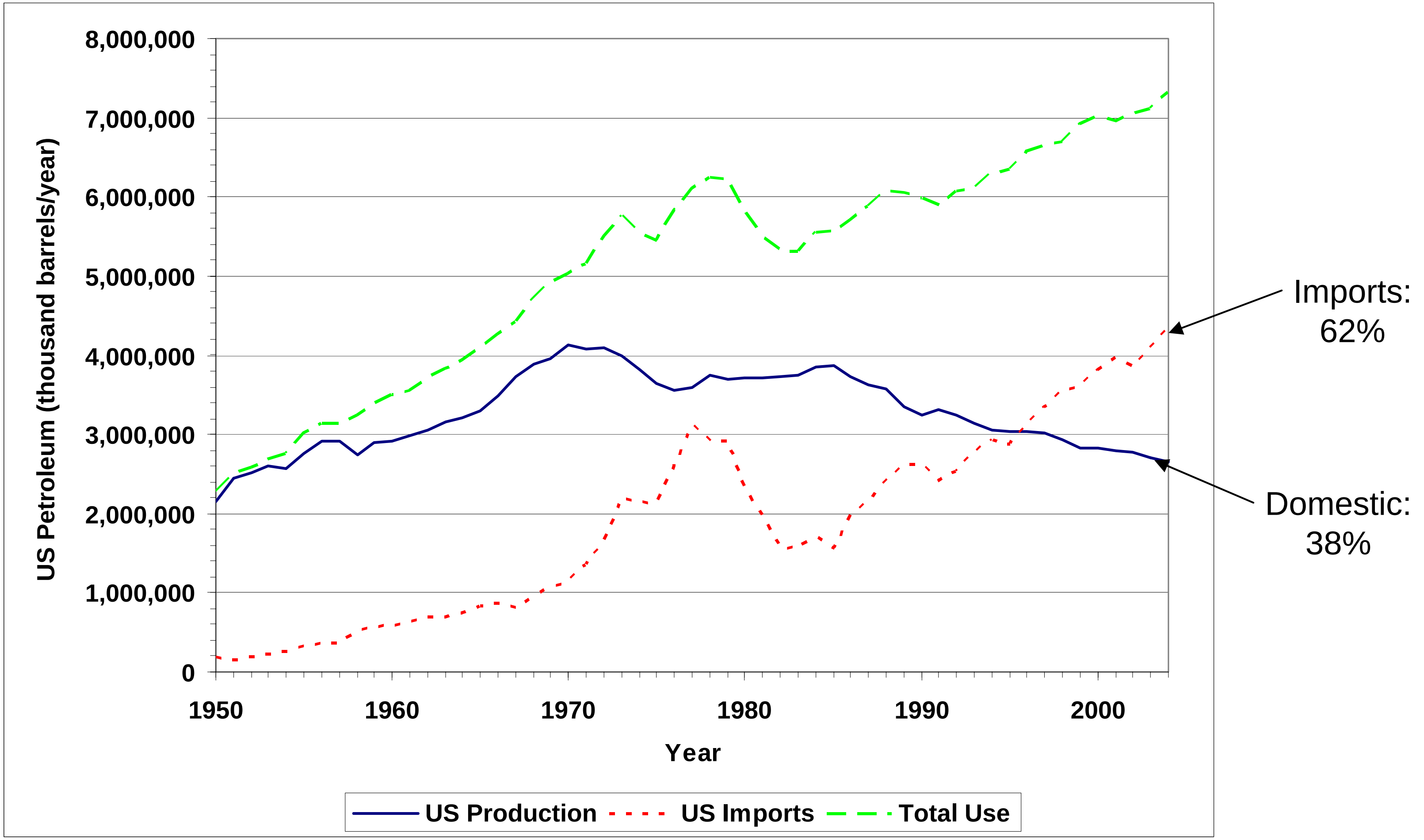
# Introduction

- Global energy needs/national security
  - 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
    - Corn grain is most heavily utilized substrate

# US Petroleum Supply & Demand






*EIA, 2005*

# Introduction

- Concern over resource inputs & outputs
  - Led to many Life Cycle Assessment studies
    - Have become focal point
      - Public discussions
      - Policy analyses

*Does Ethanol Pay ???*

Andress (2002), Kaltschmitt et al. (1997), Kim and Dale (2002, 2004), Lynd and Wang (2004), Shapouri et al. (1995, 2002, 2003a, 2003b), Sheehan et al. (2002, 2004)

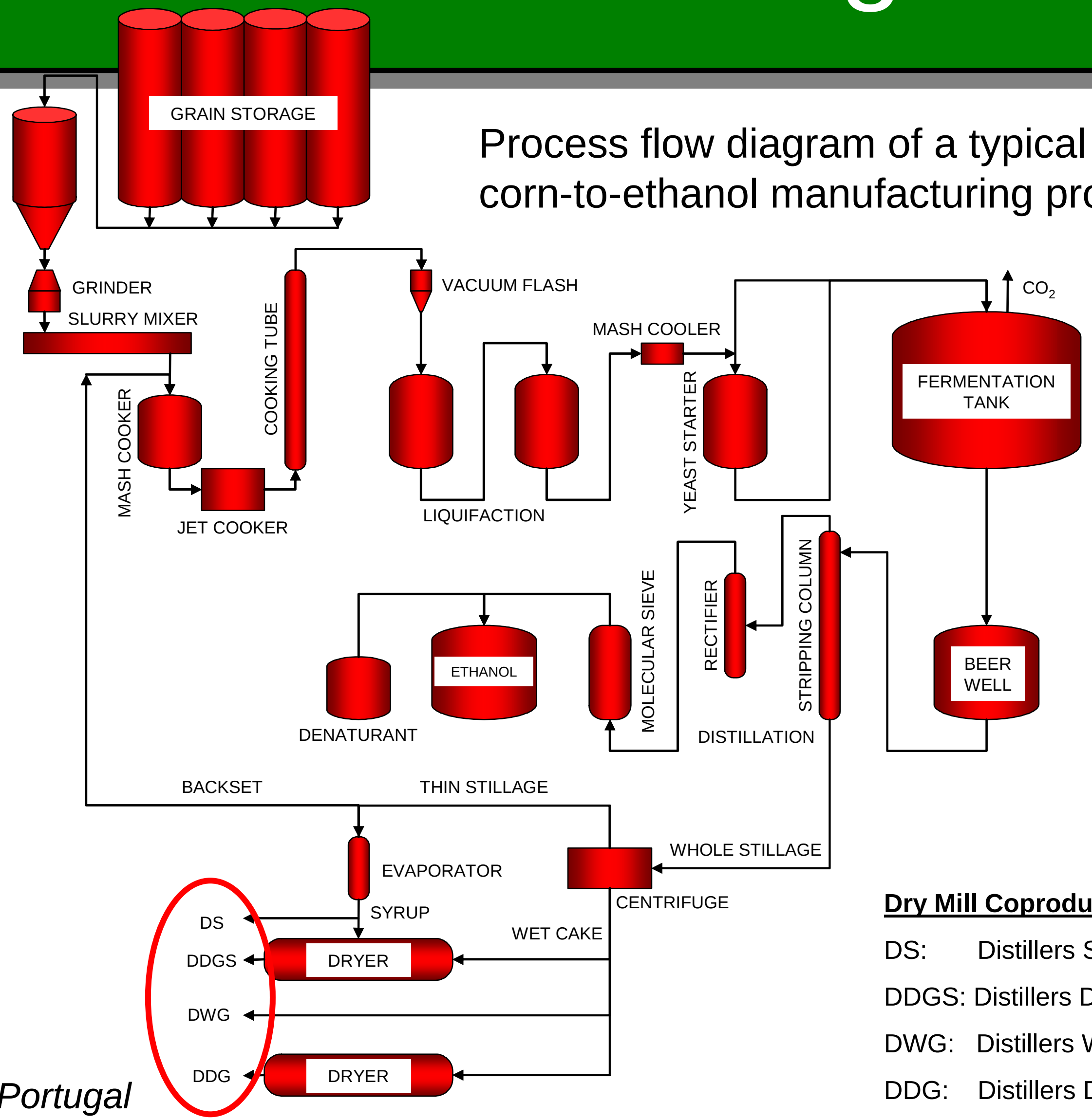
- Each manufacturing facility
  - Must contribute to mission of sustainability
    - Residues/coproducts are essential

# Today’s Outline

1) Ethanol manufacturing – process & coproducts
2) Current trends
3) What are the industry’s needs?
4) Addressing these issues
5) 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 Manufacturing

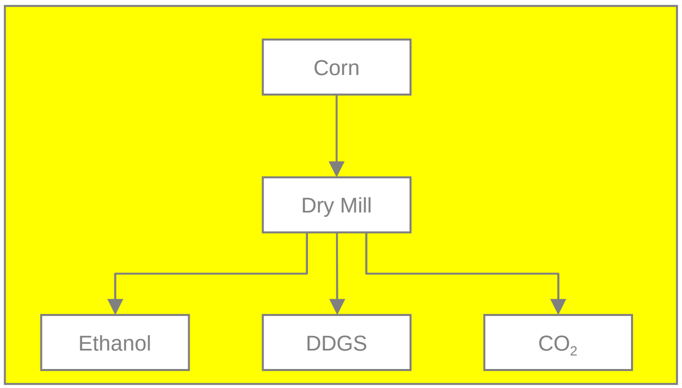
- Dry grind manufacturing
  - 3 main products
    - Primary: fuel ethanol
    - Secondary: $CO_2$ & non-fermentable components
  - Anecdotally
    - 1 kg corn = 1/3 kg ethanol + 1/3 kg $CO_2$ + 1/3 kg DDGS
  - Actuality: broad range of conversion rates
    - 1 kg corn = 0.388 L ethanol
    - 1 kg corn = 0.282 – 0.323 kg DDGS
    - 1 kg corn = 0.287 – 0.329 kg $CO_2$

*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 Manufacturing Residues

General Process




Carbon Dioxide and Steam

Nonfermentable residues – distillers solubles (DS).


Nonfermentable residues – distillers dried grains (DDG).

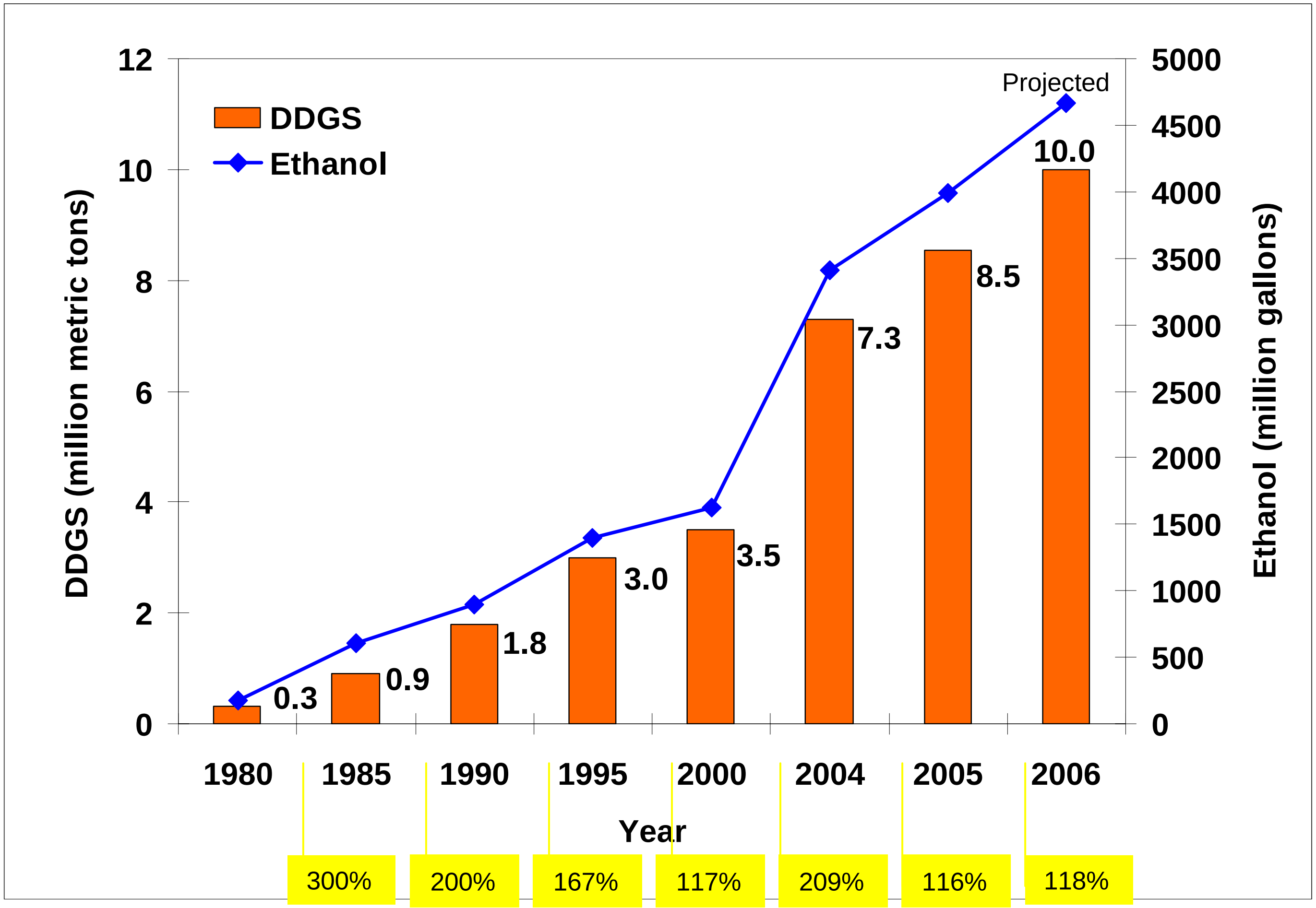

# Ethanol is a Key Player

- US fuel ethanol industry
  - Rapid growth in recent years
    - 2005: 87 plants, 4.2 billion gal/yr (15.9 billion L/yr)
    - 2006: 16 new plants, additional 1.1 billion gal/yr (4.2 billion L/yr)
    - US Energy Bill: 7.5 billion gal/yr (28.4 billion L/yr) by 2012

BBI, 2005

- As ethanol production capacity grows
  - So too does growth in manufacturing coproducts
    - Dry grind plants
      - Distillers Dried Grains with Solubles (DDGS)

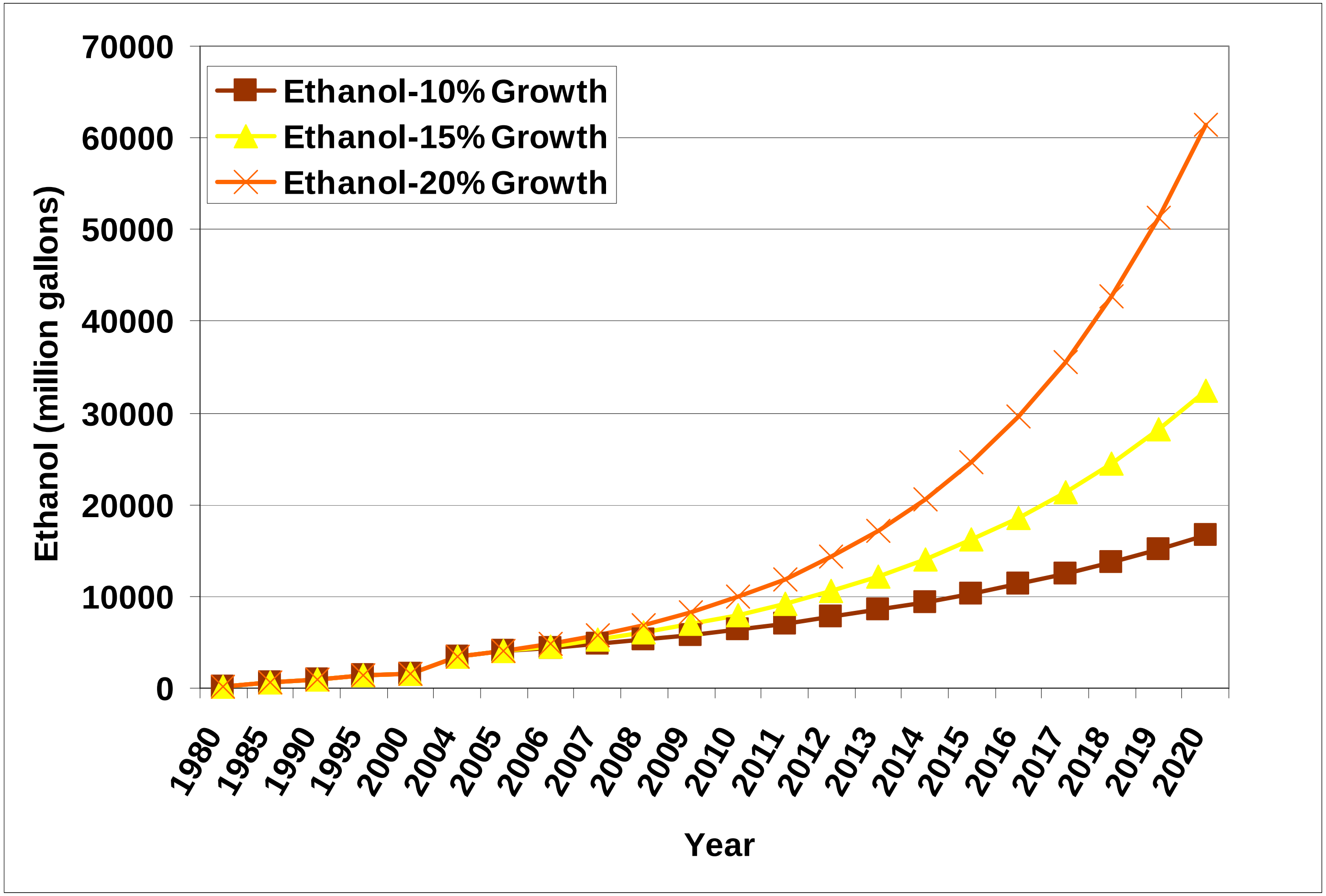
# Trends in Ethanol Production






*Adapted from UMN, 2005*

# Trends in Ethanol Production



# Coproduct Utilization

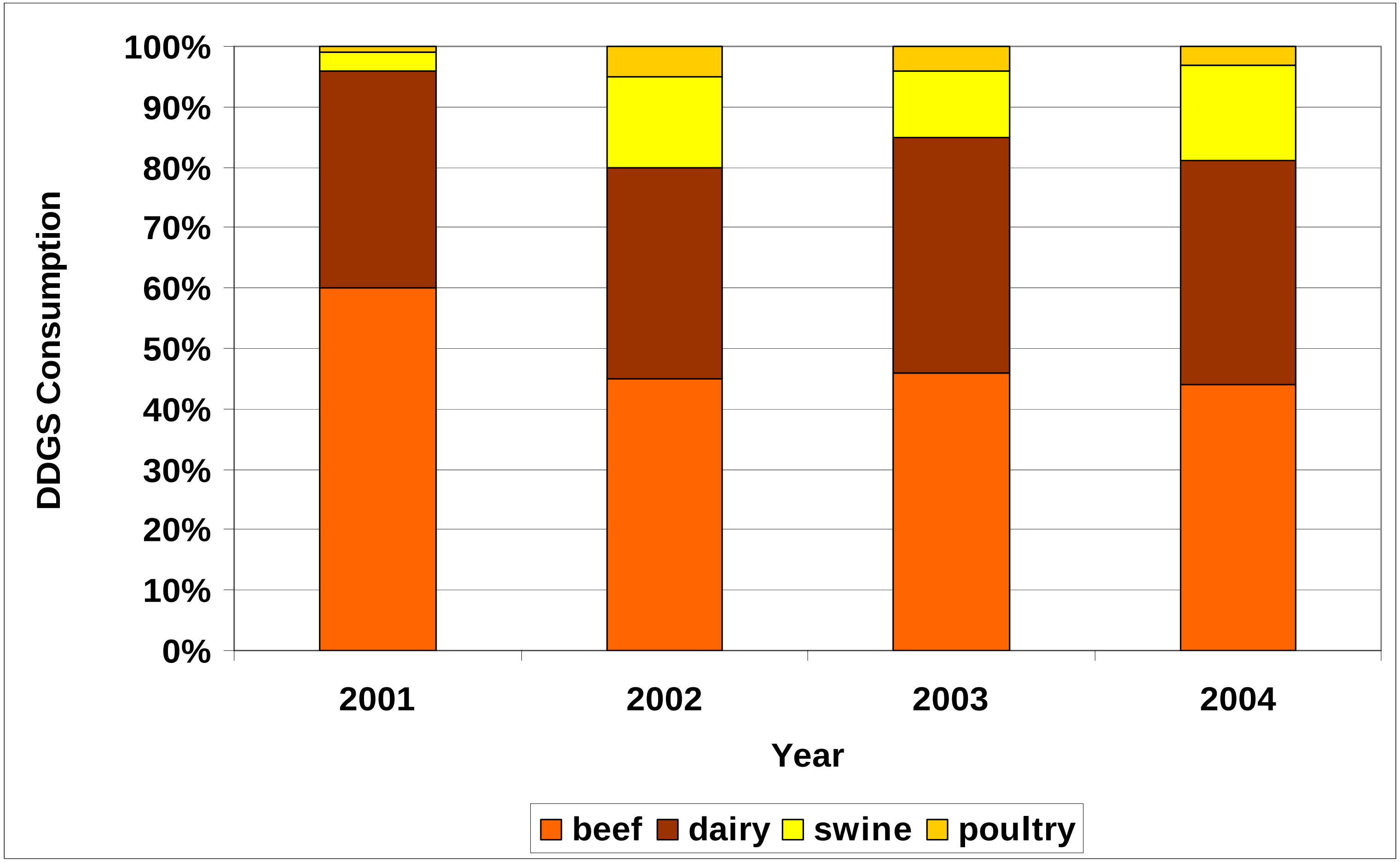
- Sales of coproducts
  - Substantial revenue source for ethanol processors
  - Vital to profitability
- As the industry continues to expand
  - How will marketplace handle increasing demand for corn?
  - How will marketplace handle increasing supply of DDGS?

| Per 1 ton of DDGS | |
|---|---|
| Value of DDGS ($/ton DDGS) | Value to Ethanol ($/L ethanol) |
| 80 | 0.062 |
| 100 | 0.078 |
| 120 | 0.093 |

# Coproduct Utilization

- Currently
  - Primary outlet for nonfermentable residues (coproducts)
    - **<u>DDGS</u>**
    - Others
      - DDG, WDG, WDGS, CDS, etc.
    - Livestock feeds
      - Dairy, beef, swine, poultry
      - Excellent feed ingredients
      - Numerous research studies (UMN, 2006)
      - Much work remains – maximize/optimize

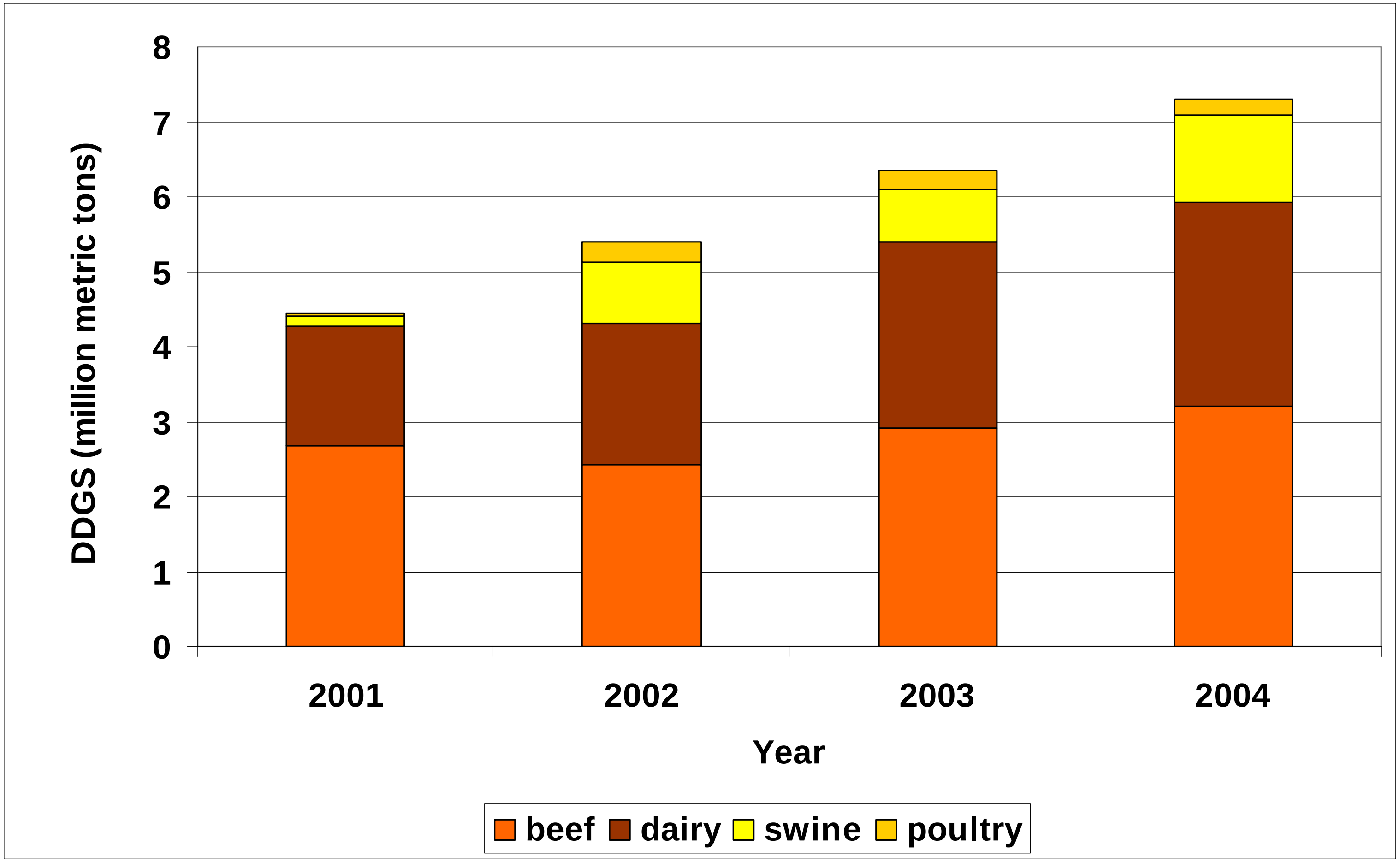
# DDGS Utilization



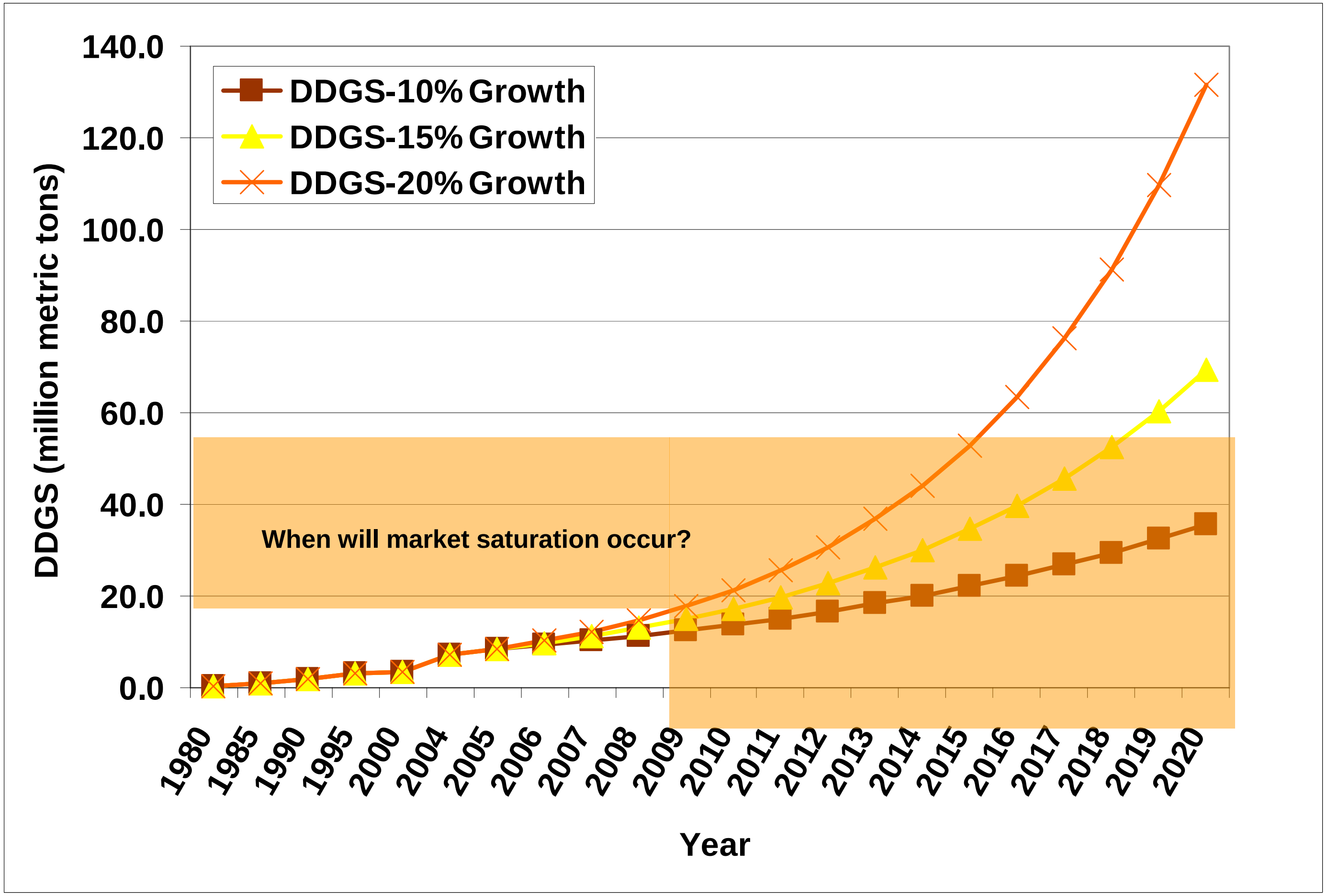



*Adapted from UMN, 2005*

# DDGS Utilization



# Projected Coproduct Growth



# Coproduct Utilization

- How much can be used as livestock feed?
  - 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 need to ask:
  - What are the industry’s current needs?
  - What other possibilities exist?

# What are the Industry's Needs?

- Focus group meeting
  - Held on June 2, 2005
  - At USDA-ARS research laboratory in Brookings, SD
- 50 participants
  - Government agency officials (local, state, federal)
  - SD Congressional delegation
  - Livestock producers
  - Ethanol industry
    - Processors
    - Marketers
    - Research & development
  - University research faculty

South Dakota & north central region of US

# What are the Industry's Needs?

- Purpose of the focus group
  - To determine current needs of
    - Companies that produce distillers grains
    - Customers that utilize distillers grains

- Identify
  - Current constraints
  - Future directions

# Three Primary Objectives

1) Identification of major issues
   - That impact value of distillers grains
   - Current and future

2) Identification of specific research needs

3) Prioritization of these research needs

# Major Issues Affecting DDGS Utilization

- Amino acid digestibility
- Availability and pricing of alternative feeds
- Correct nutrient values for specific species
- DDGS form – grain, pellet, cake, tub
- DDGS produced by old vs. new plants
- Design of equipment and facilities
- Distribution problems – distance from markets
- Educating livestock producers on the use of DDGS
- Effect on feed efficiency
- Effect on growth rate
- Energy consumption in plants (for drying DDGS)
- Environmental impacts – phosphorus, microbes, water content
- Evaluation of carcass effects
- Extracting oil – production of biodiesel
- Feed analysis tags
- Fiber content
- Flowability
- Food uses – cookies, breads, pastas
- Fractionation of nutrients – oil, fiber, protein
- Handling concerns – bulk density, pelleting, cubing
- Limiting inclusion rates due to nitrogen, phosphorus, sulfur in animal manure

Many participants

Many perspectives

# Major Issues Affecting DDGS Utilization

- Maintaining quality during processing, handling, and storage
- Maximum inclusion rates
- Mycotoxin content potential
- Nutrient digestibility
- Nutrient energy evaluation versus traditional rations
- Nutrient/manure management plans
- Oil content
- Other options for DDGS use beyond livestock - crop fertilizer, foods, industrial
- Product consistency/variability – color, particle size, nutrient quantity and quality
- Rapid, non-destructive tests – (NIRS)
- Seasonality in DDGS nutrient content
- Species-specific livestock markets – beef, dairy, swine, poultry
- Standard analytical laboratory methods
- Storage and handling of wet products
- Target animals – need more research for poultry, swine, fish, petfoods
- Tech-transfer to producers and the public
- Transportation – flowability, costs, rail, truck, off-loading
- Use in non-ruminant rations
- Value-added products that can be made from DDGS
- Wet vs. dry DDGS

# Research Needed to Address these Issues

- Cellulosic fermentation coproducts
- Densification
- Developing and augmenting species-specific markets – dairy, beef, swine, poultry
- Developing livestock feeds with higher value – designer feeds
- Educational activities for livestock producers – benefits of using distillers grains
- Environmental issues – manure and soil management
- Flowability
- Fractionating nutrients into concentrated streams – protein, fiber, oil
- Improving nutritional content, quality, and value – nutrient digestibility/availability
- Phosphorous levels
- Protein, oil, fiber contents
- Standard analytical laboratory methods – especially moisture determination
- Transportation issues – product form (pelleting)
- Utilizing next generation coproducts from new ethanol processes (dry-grind modifications)
- Utilization guidelines

Many of us are already addressing these issues

# Top 10 Research Priorities

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

- Briefly review our efforts
  - USDA – ARS, NCARL, Brookings, SD
  - Some of these research priorities

# Addressing These Issues

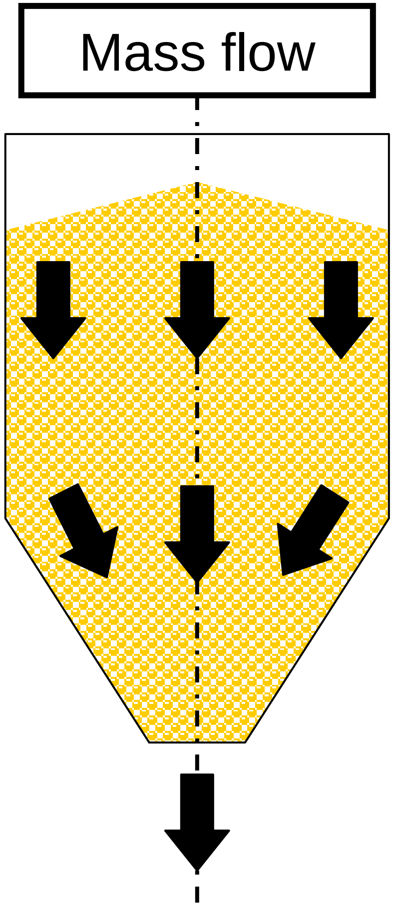
- NCARL's research objectives

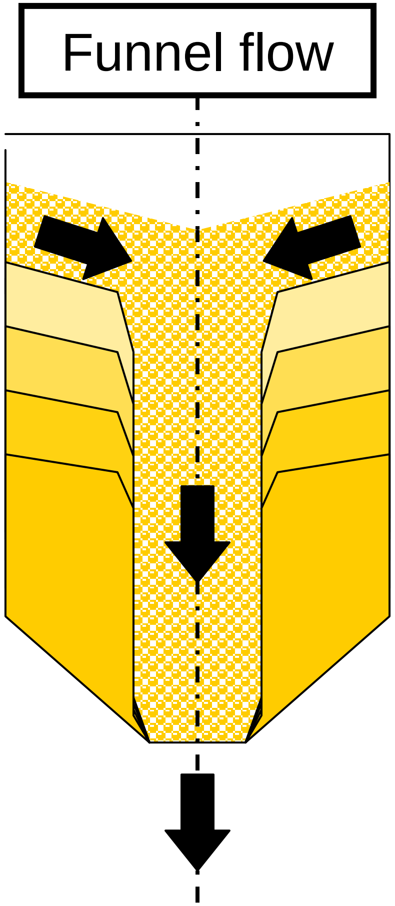
1) Identify, characterize, quantify, and improve flowability and storability behavior of DDGS
2) Develop and improve conversion processes for value-added products from DDGS
   a) Animal feeds
   b) Food ingredients
   c) Industrial products

# Flowability

- Objective #1 – Storability & Flowability
  - Significant constraint to long-distance transportation of DDGS
    - Inter-particle bridging & caking
      - Rail cars & storage structures do not unload (~5-10%)
    - Currently result in economic losses
      - Large railroads no longer ship DDGS with their cars
        - » Rail car damage & repair
        - » Marketers & ethanol plants must own cars
  - Goals
    - Identify, characterize, and determine the cause
      - Physical and chemical properties of DDGS
    - Develop methods to prevent or reduce occurrence

# Flowability




# Flowability

# Flowability

**Objective** (initial studies)

- Examine the effects of moisture content and soluble levels on the resulting physical and chemical properties of DDGS

**Independent**

- Soluble Content: 10, 15, 20, & 25% (db)
- Moisture Content: 10, 15, 20, 25, & 30 % (db)

**Dependent**

- Physical Properties
  - Carr indices – ASTM D6393
    - Bulk density: aerated and packed (g/cc)
    - Angle (Repose, Fall, Spatula) ($^o$)
    - Compressibility (%)
    - Particle size distribution – Uniformity (-)
    - Dispersibility (%)
  - Color – Hunter L,a,b (-)
- Chemical Properties
  - Fat
  - Protein

# Flowability

## Results

| Property | MC (%db) | Soluble (%db) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 10 | | 15 | | 20 | | 25 | |
| | | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| *Flow Index (-) | 10 | 79.50 a | 0.50 | 78.33 a-c | 0.83 | 80.00 a | 0.00 | 80.00 a | 0.00 |
| | 15 | 77.67 a-d | 1.20 | 75.17 d-f | 0.44 | 78.00 a-d | 1.53 | 79.33 ab | 1.20 |
| | 20 | 77.33 a-d | 1.45 | 76.33 b-f | 1.17 | 78.83 ab | 0.17 | 78.33 a-c | 1.20 |
| | 25 | 75.33 c-f | 1.20 | 74.00 f | 2.31 | 78.33 a-c | 1.20 | 78.83 ab | 0.73 |
| | 30 | 75.67 c-f | 0.88 | 73.67 f | 0.67 | 77.17 a-e | 0.44 | 74.17 f | 1.01 |
| **Flood Index (-) | 10 | 59.25 ab | 0.00 | 56.25 a-e | 0.25 | 58.67 ab | 2.19 | 61.00 a | 2.31 |
| | 15 | 57.83 a-c | 2.68 | 56.42 a-e | 0.60 | 57.83 a-c | 1.76 | 53.08 c-e | 1.08 |
| | 20 | 55.33 b-e | 2.03 | 57.50 a-d | 0.52 | 56.92 a-e | 1.16 | 52.42 de | 2.29 |
| | 25 | 57.00 a-e | 3.83 | 55.92 a-e | 1.72 | 53.25 c-e | 0.14 | 51.75 e | 2.98 |
| | 30 | 54.50 b-e | 1.25 | 56.58 a-e | 0.36 | 54.92 b-e | 2.44 | 52.75 c-e | 1.46 |

*** Flowability**
70-79: Fair
80-89: Good
90-100: Excellent

**** Floodability**
40-59: Inclined to flood
60-79: Floodable
80-100: Very floodable

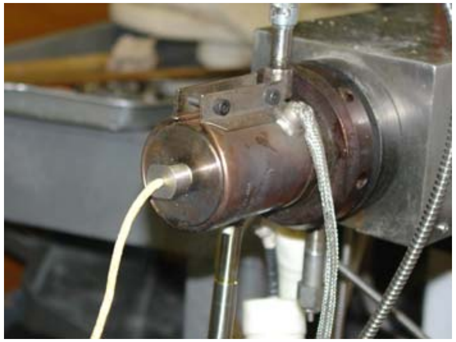
- Fair-to-good flowability
  - Somewhat unstable (floodable) flow
  - Have not quite encapsulated cause of flowability issues in transportation
- Next steps
  - Consolidation with time + chemical reactions (cooling after drying)
  - Compression/compaction – Jenike shear cell
    - Effects of bulk storage
    - Vibration in transportation



*Ganesan et al., 2005*

# Animal Feeds

- Objective #2a – Value-Added Materials
  - Livestock nutrition research – ubiquitous (UMN, 2005)
  - Goal
    - Develop and optimize processes to
      - Convert DDGS into high-value feeds
        - » Aquaculture feeds
        - » Pet foods
        - » Extrusion processing



# Aquaculture Feeds

## Historically: some DDGS research / little market utilization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Currently many opportunities

# Aquaculture Feeds

**Objective** (initial studies)

- To study the effect of feed and processing parameters on the resulting physical properties of extruded feed

**Independent**

- Formulation: 3 isocaloric feeds (360 kcal/100gram) with 20, 30, 40% (db) DDGS
- Moisture content: 15,20,25% (db)
- Screw speed: 130,160,190 rpm

**Dependent**

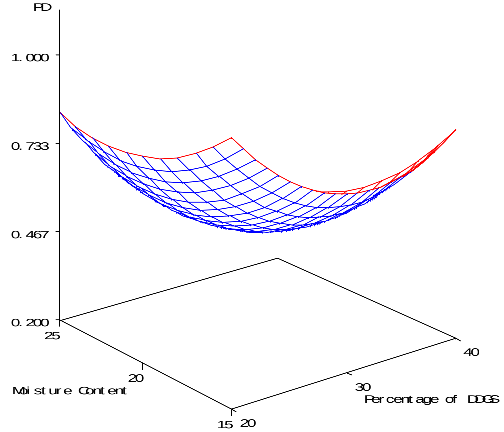
- Material throughput (kg/hr)
- Bulk density (kg/$m^3$)
- Durability (%)
- Porosity (%)
- Specific gravity (-)
- Color (-)

| Feed Ingredients | Weight of ingredients (g/96g) | | |
|---|---|---|---|
| | 20% DDG | 30% DDG | 40% DDG |
| DDGS | 20 | 30 | 40 |
| Soy flour | 32 | 28 | 24 |
| Corn flour | 35 | 29 | 23 |
| Fish meal | 6 | 6 | 6 |
| Mineral mix | 1 | 1 | 1 |
| Vitamin mix | 2 | 2 | 2 |

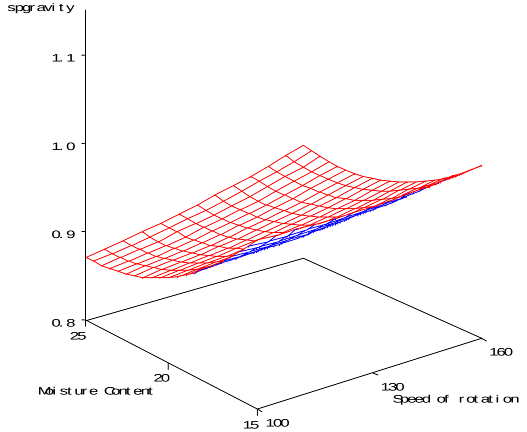
# Aquaculture Feeds

**Results**

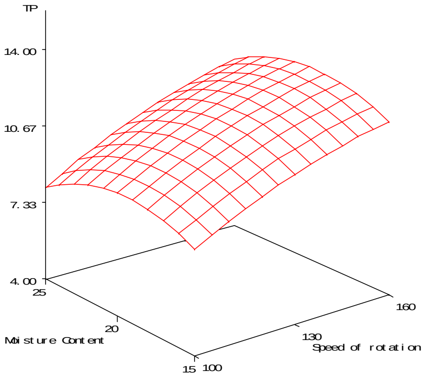
Response Pellet Durability



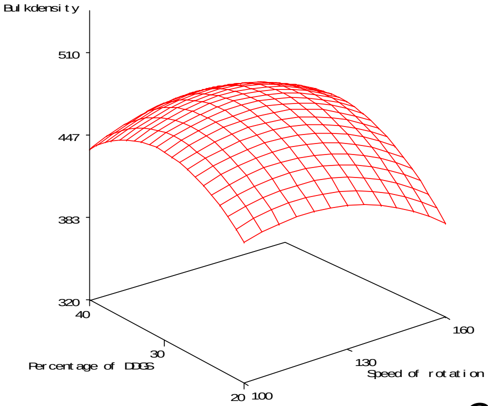

Response on Specific gravity



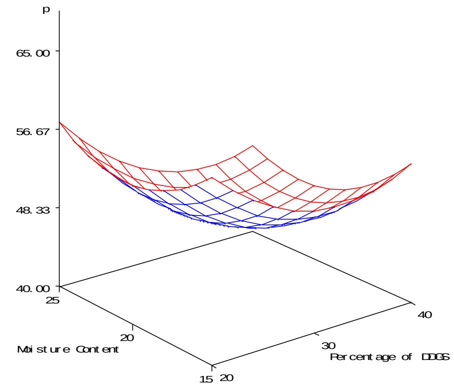

Response on Throughput




Response Bulk Density




Response on porosity






*Chevanan et al., 2005a*

# Aquaculture Feeds

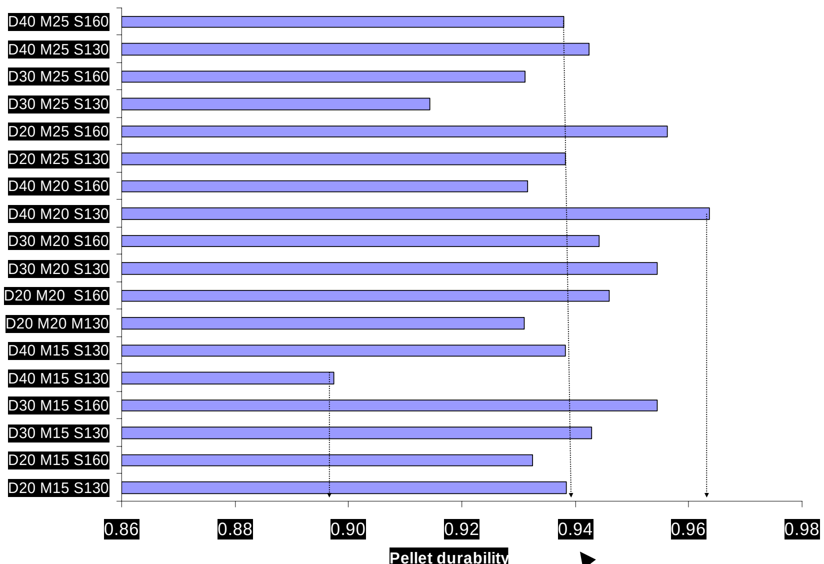
- Key results
  - DDGS is a very good source base material for aquaculture feeds
  - Bulk density: from 328 to 487 $kg/m^3$ (mean=418 $kg/m^3$ )
  - Pellet durability: from 18 to 96% (mean=70%)
  - Specific gravity: from 0.82 to 1.05 (-) (mean=0.94)

- Major challenge
  - Material bonding – lack of starch

- Next stage
  - Whey protein
    - Commonly used as a feed binder and protein source

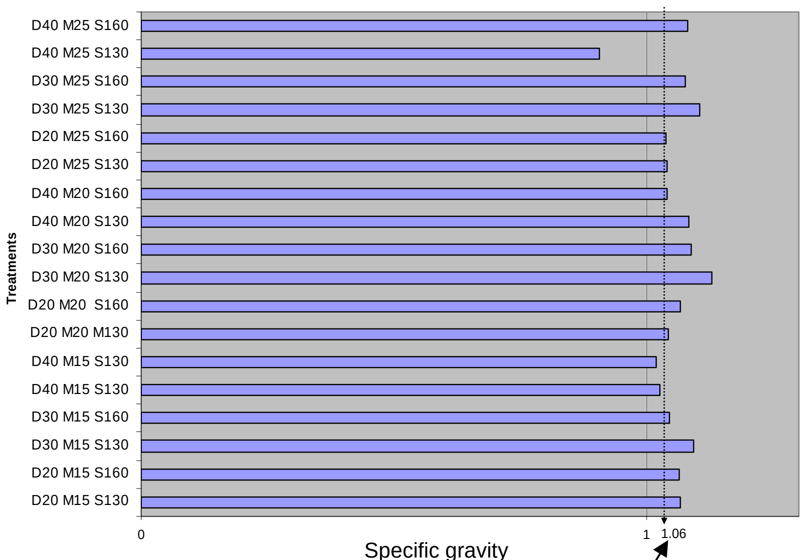
# Aquaculture Feeds

## Pellet durability




vs. 0.70

## Specific gravity




vs. 0.94

- Next steps
    - Process optimization
    - Feeding trials



*Chevanan et al., 2005b*

# Implications & Future Directions

- Achieving these specific project objectives
  - Will help address some current industry needs
    - New & refined methods for handling and storage
    - Value-added applications
      - Feed, food, industrial products
        - » New market opportunities
  - Potential for benefits
    - Ethanol processors
    - Livestock producers

# Implications & Future Directions

- Achieving not only these objectives
  - But also addressing current challenges & constraints

  - Will be key as DDGS evolves
    - Dynamic industry
      - “Next generation” products
        - » Fractionation
        - » Enzymes/fermentation technology
        - » Novel process modifications
    - Impact coproduct generation & properties
      - Physical, chemical, functional properties
      - Alter utilization opportunities

# Acknowledgments

- Many thanks to those who have contributed to the project thus far…


K. Boateng
W. Bokhoven
P. Brown
N. Chevanan
S. Colby
T. Cooper
R. Flores
R. Fuller
V. Ganesan
R. Garcia
K. Hicks
M. Janes

J. Julson
K. Kephart
P. Krishnan
D. McCalla
K. Muthukumarappan
A. Otieno
M. Schlicher
M. Stowers
B. Tatara
J. Visser
P. Weimer
G. Williams

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# Thank You

- Questions?
- Comments?