Ethanol Production in US

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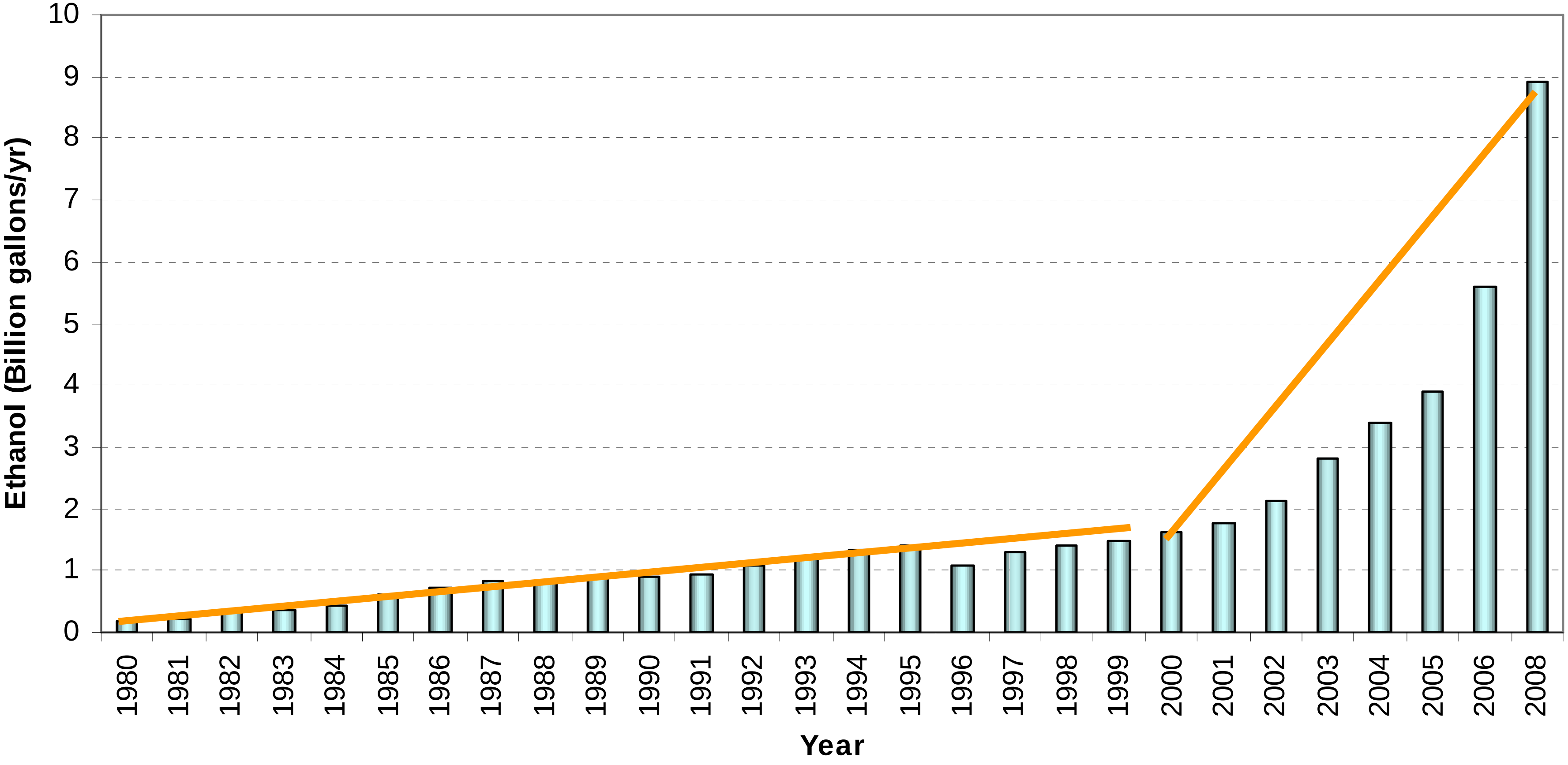
- Bob Moreau — ERRC/ARS/USDA
- Eberhard Morgenroth — University of Illinois
- Ganti Murthy — Oregon State University
- Kent Rausch — University of Illinois
- Vijay Singh — University of Illinois
- Mike Tumbleson — University of Illinois

Presentation Outline

- Ethanol Production Process (Video)
- Ethanol Industry
  - Ethanol Production Capacity
  - Growth in Industry
- Issues Facing Ethanol Industry
- Emerging Dry Grind Ethanol Processes
- Future of Ethanol Industry
  - Cellulosic Ethanol

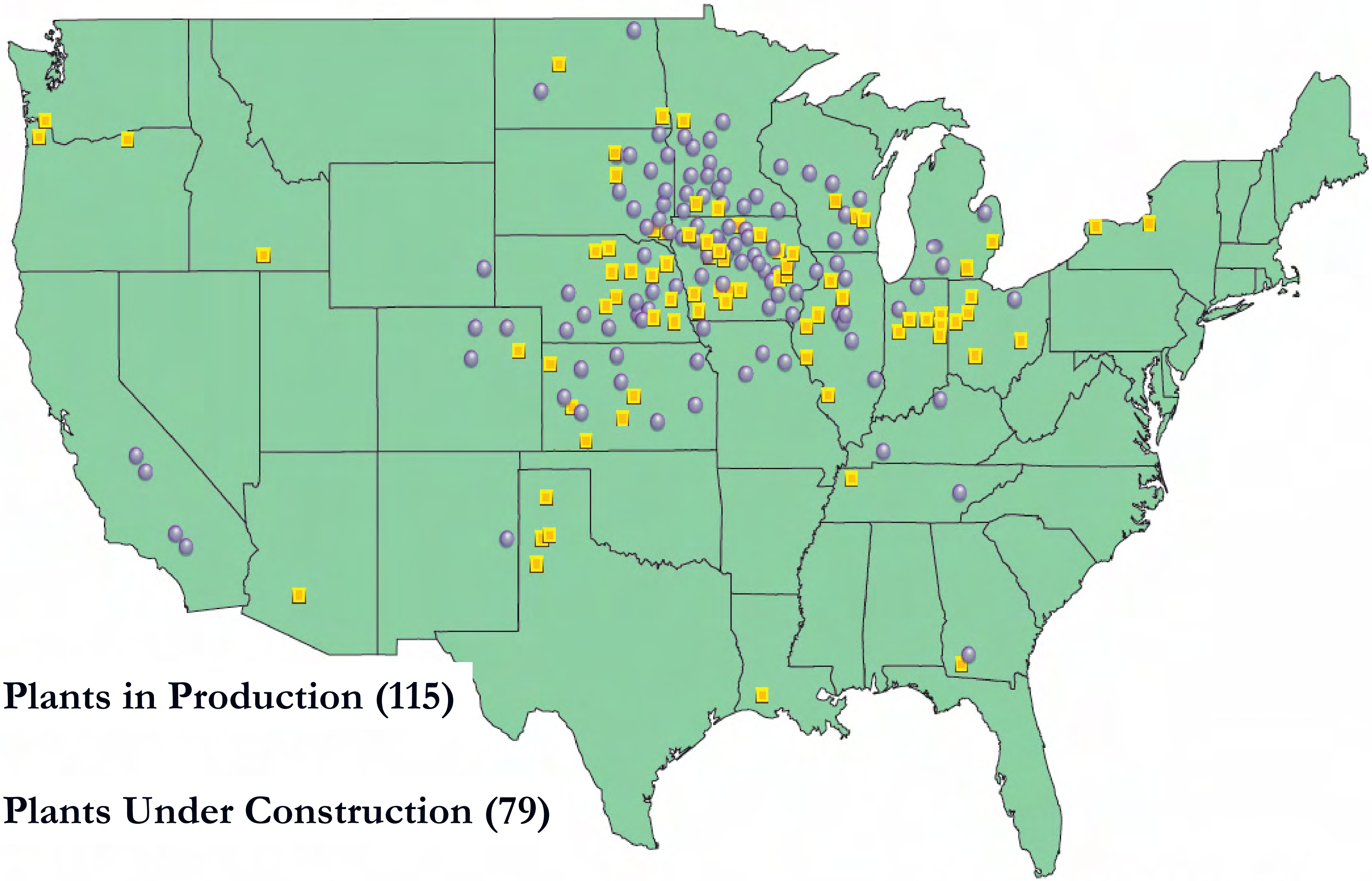
Ethanol Production Video

Ethanol Production in US



2004: 3.4 billion gallons   2006: 5.6 billion gallons   2008: 8.9 billion gallons

U.S. Dry Grind Corn Facilities

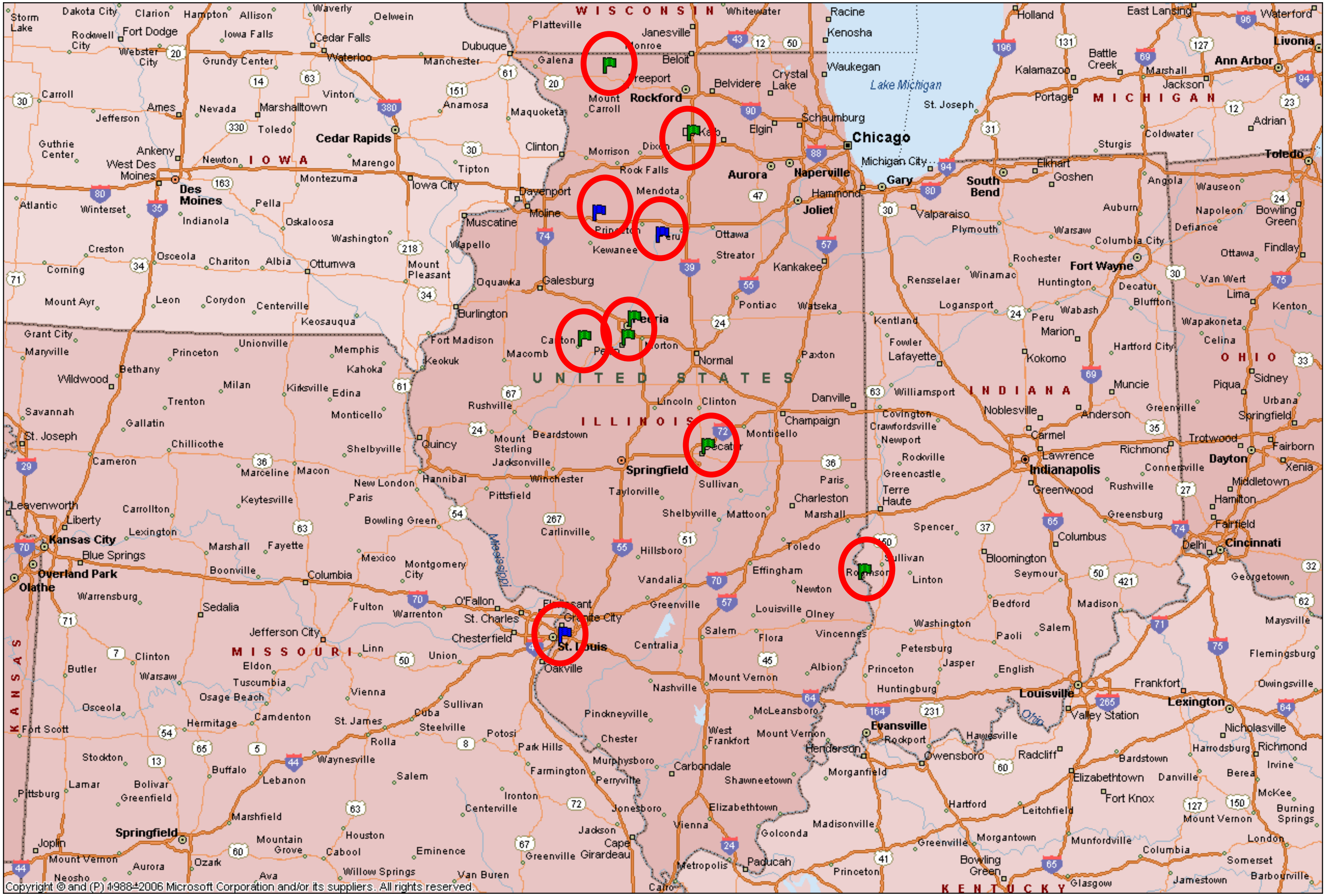


Plants in Production (115)

Plants Under Construction (79)

Source: Renewable Fuels Association
4.3.07

Dry Grind Ethanol Plants in Illinois



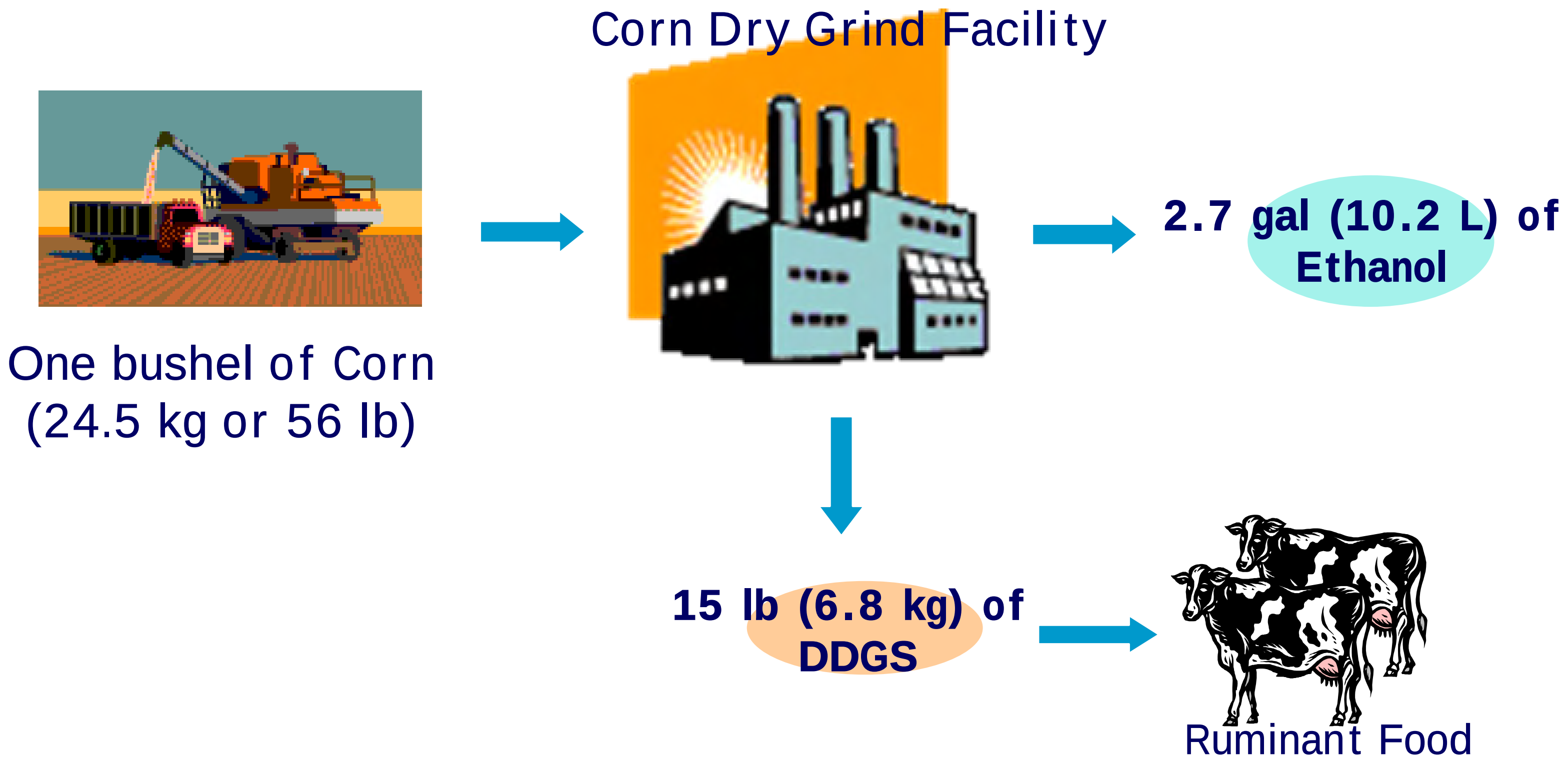
Benefits of Ethanol

- Reduces dependence on foreign oil imports
- Extend the domestic supplies of gasoline
- Environment friendly, reduces green house gases
- Increase octane rating of gasoline
- Clean burning fuel
- Increases demand for corn, stabilizes prices
- Rural Development

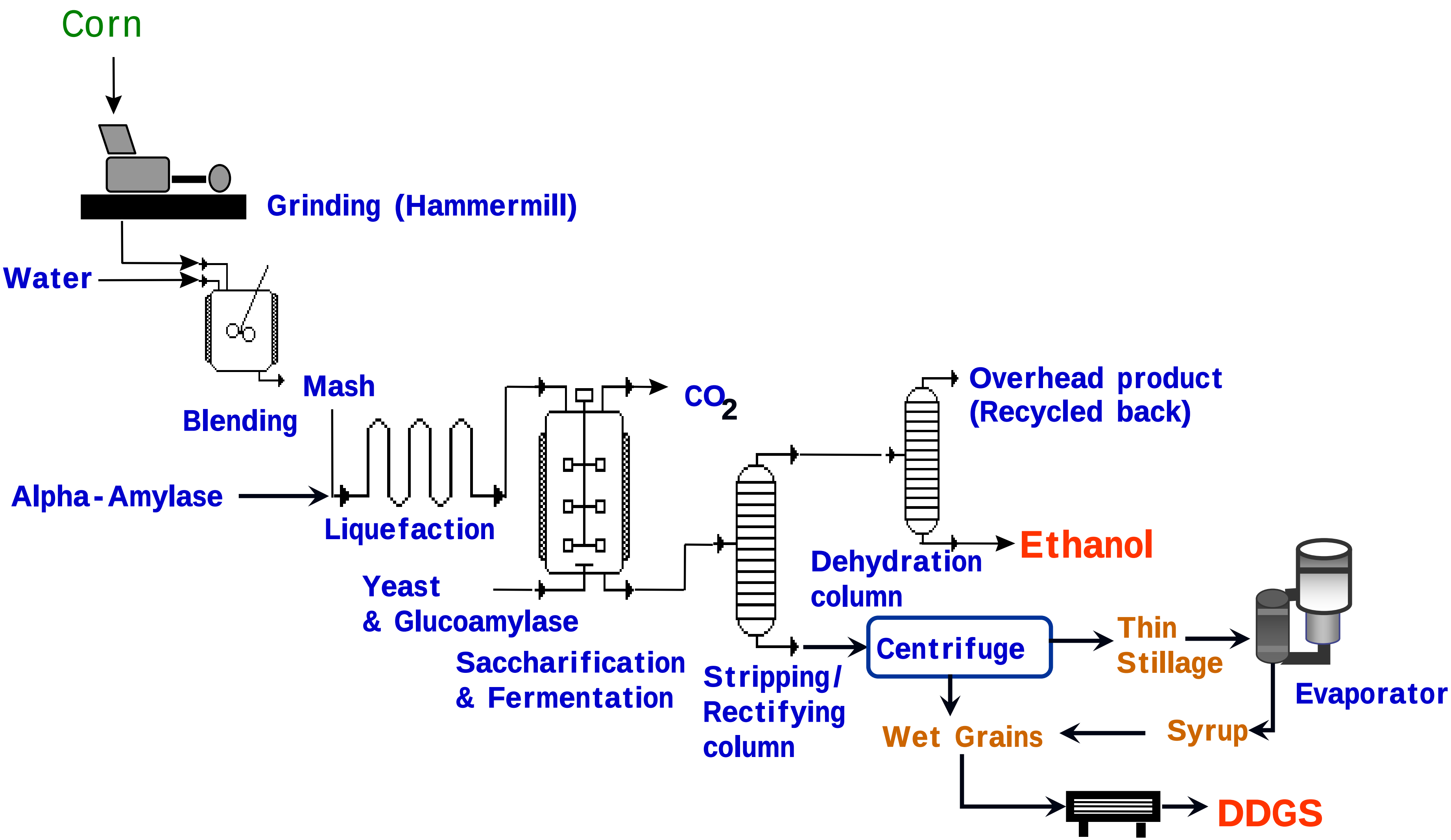
Issues Related To Ethanol Industry

- Water Used
  - Approximately 4 gallon water/gallon of ethanol produced
- Emissions/Odor
- Food versus Fuel
  - Corn is also used for human consumption
- Low Coproduct Value
- Energy Independence
  - Ethanol from corn is limited by corn production
  - Converting all the corn in the US into ethanol will only meet 20 to 25% of the annual gasoline demand

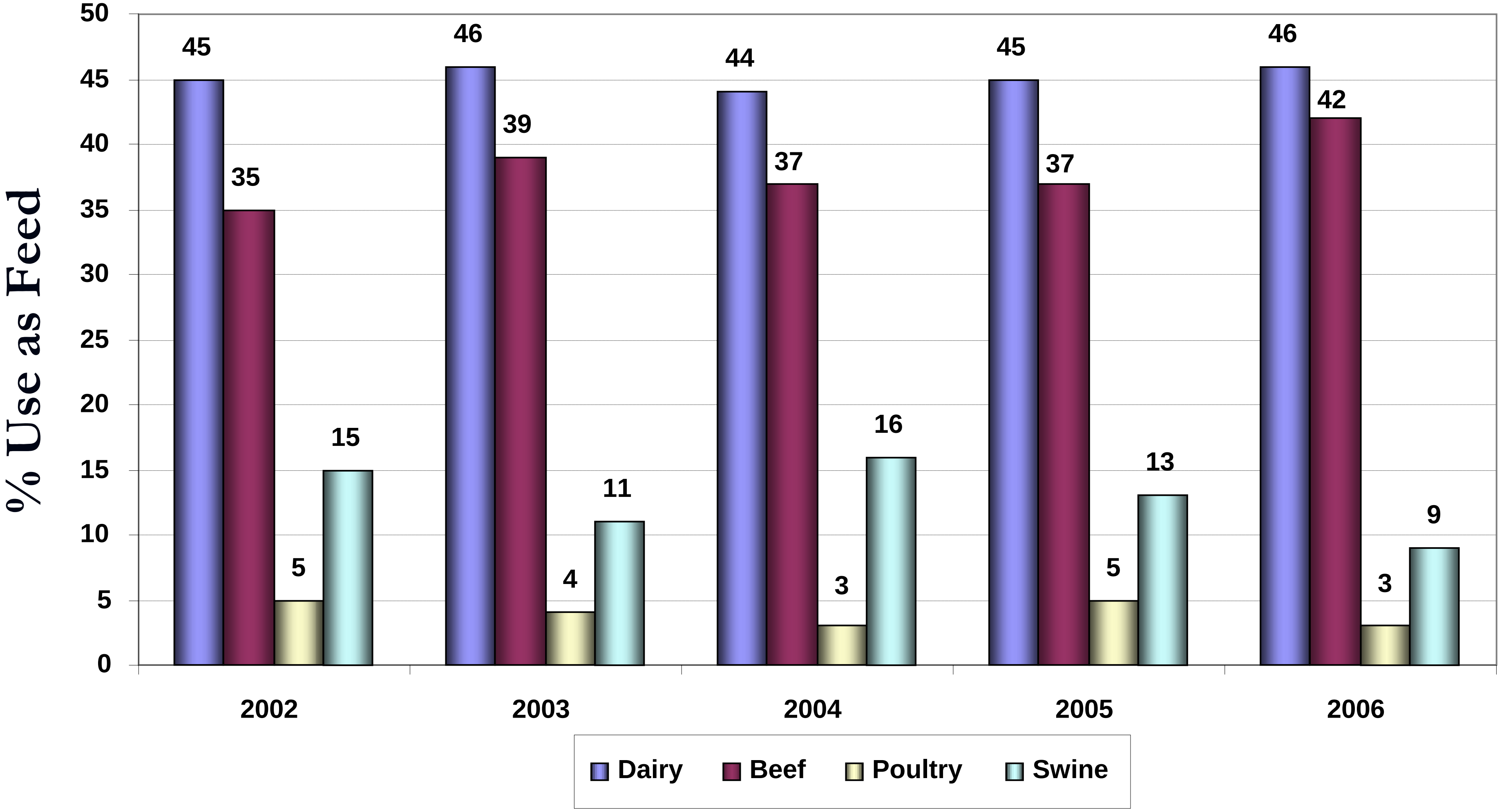
Corn Dry Grind Ethanol Process



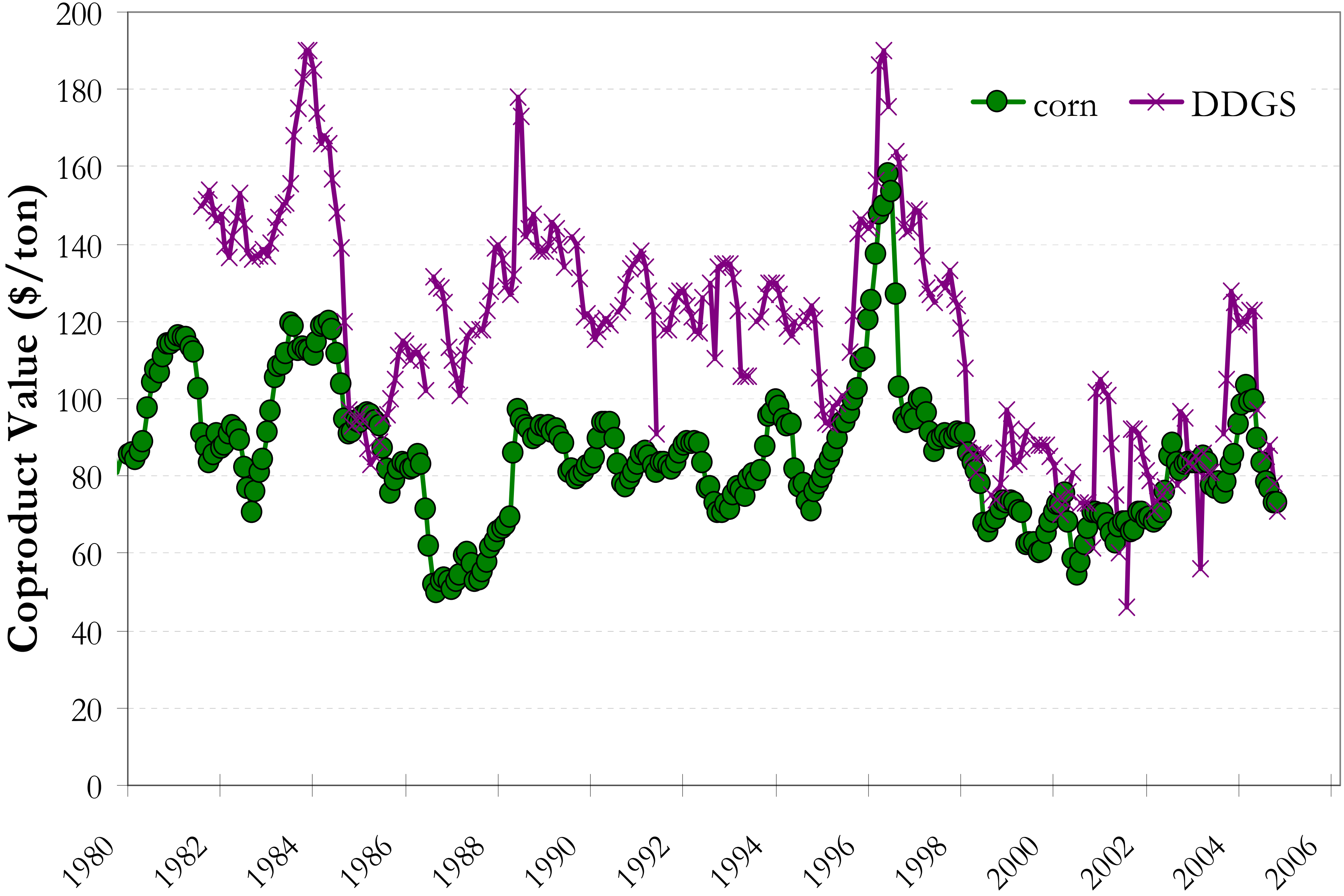
Conventional Dry Grind Process



DDGS Utilization (2005)



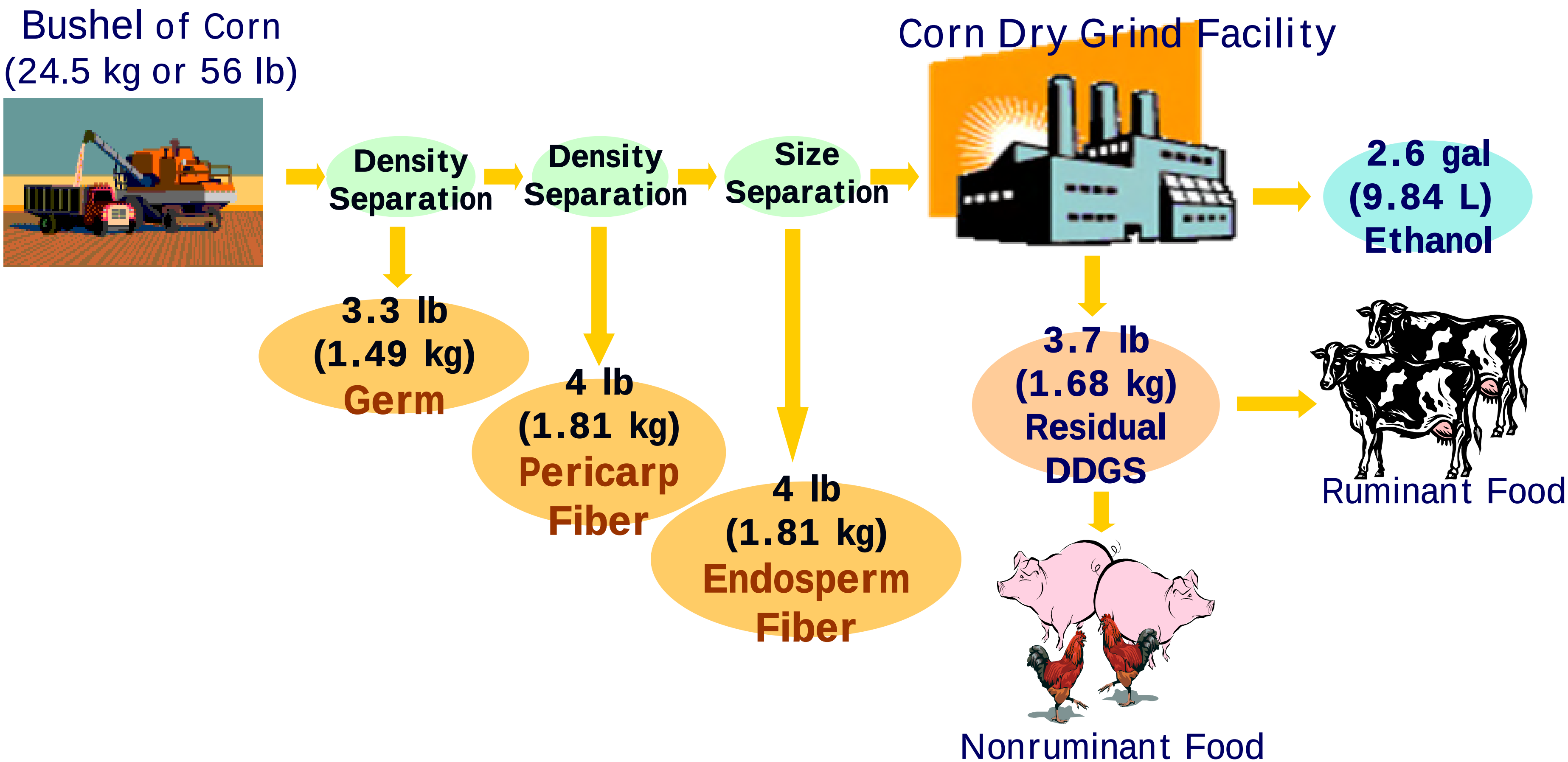
Source: Steve Markham, Commodity Specialists Company



Economic Research Service 2005: www.ers.usda.gov/db/feedgrains/

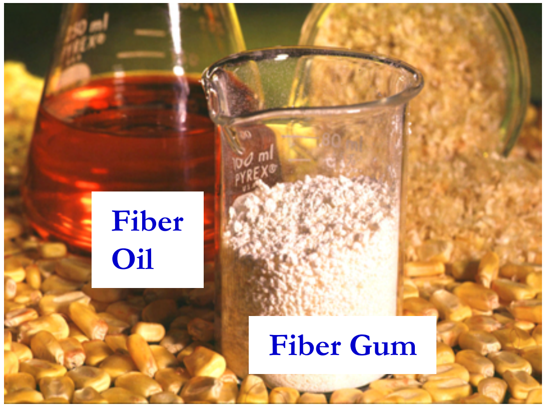
Emerging Technologies in Dry Grind Ethanol Production:
Corn Fractionation Process

Wet Corn Fractionation:
Enzymatic Dry Grind Corn Process (E-Mill)

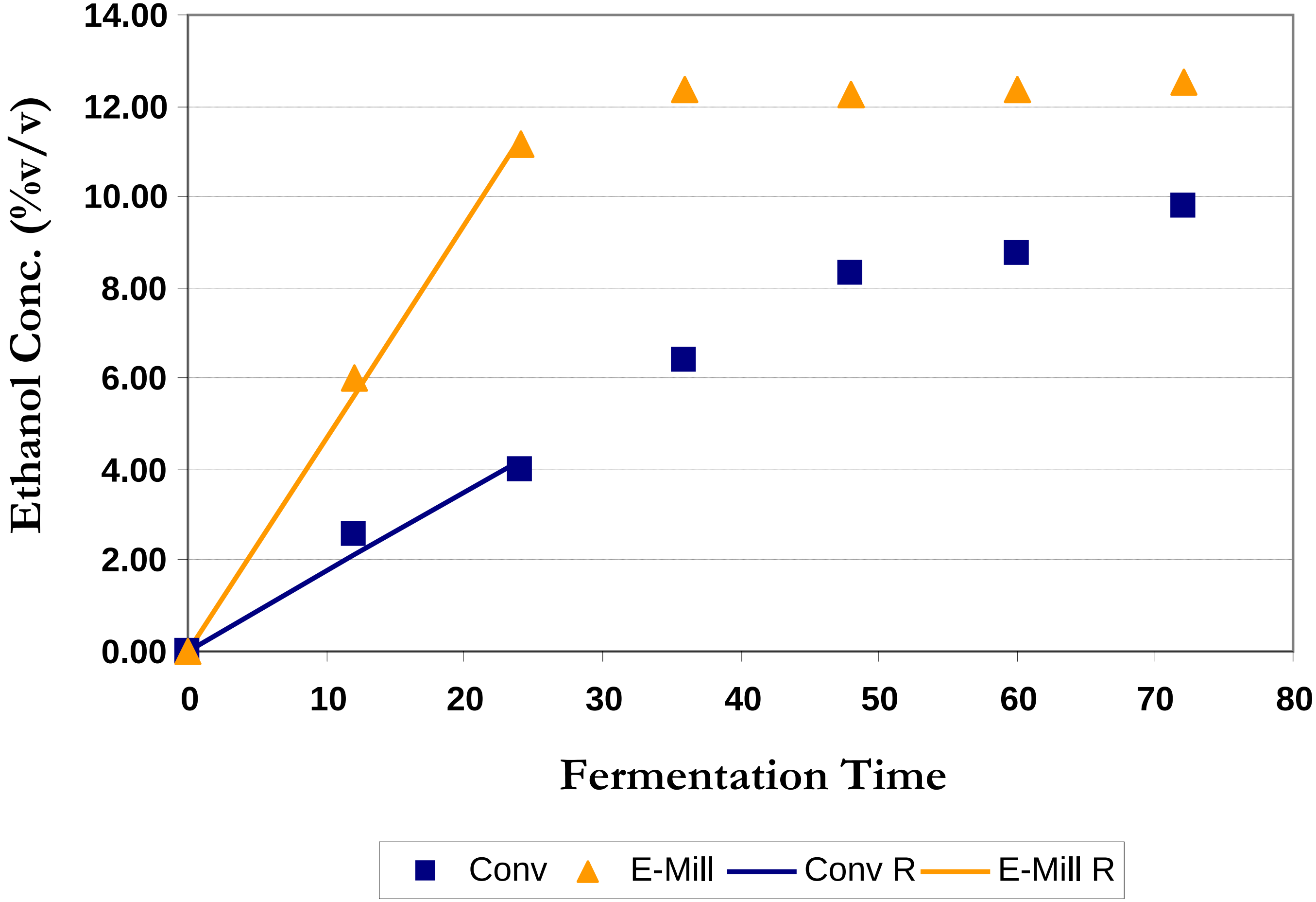


Other Benefits of Fractionation Process:
Recovery of Valuable Coproducts

- Recovery of germ, pericarp and endosperm fiber as valuable coproducts
  - Germ
    - Corn Germ Oil
  - Pericarp and Endosperm Fiber
    - Corn Fiber Oil
    - Corn Fiber Gum
    - Ethanol



Fermentation Profiles: Conventional and E-Mill Processes



Singh, V., Johnston, D.B., Naidu, K., Rausch, K.D., Belyea, R.L. and Tumbleson, M.E. 2005. Comparison of modified dry grind corn processes for fermentation characteristics and DDGS composition. Cereal Chem. 82:187-190.

DDGS Composition: Conventional and E-Mill Processes

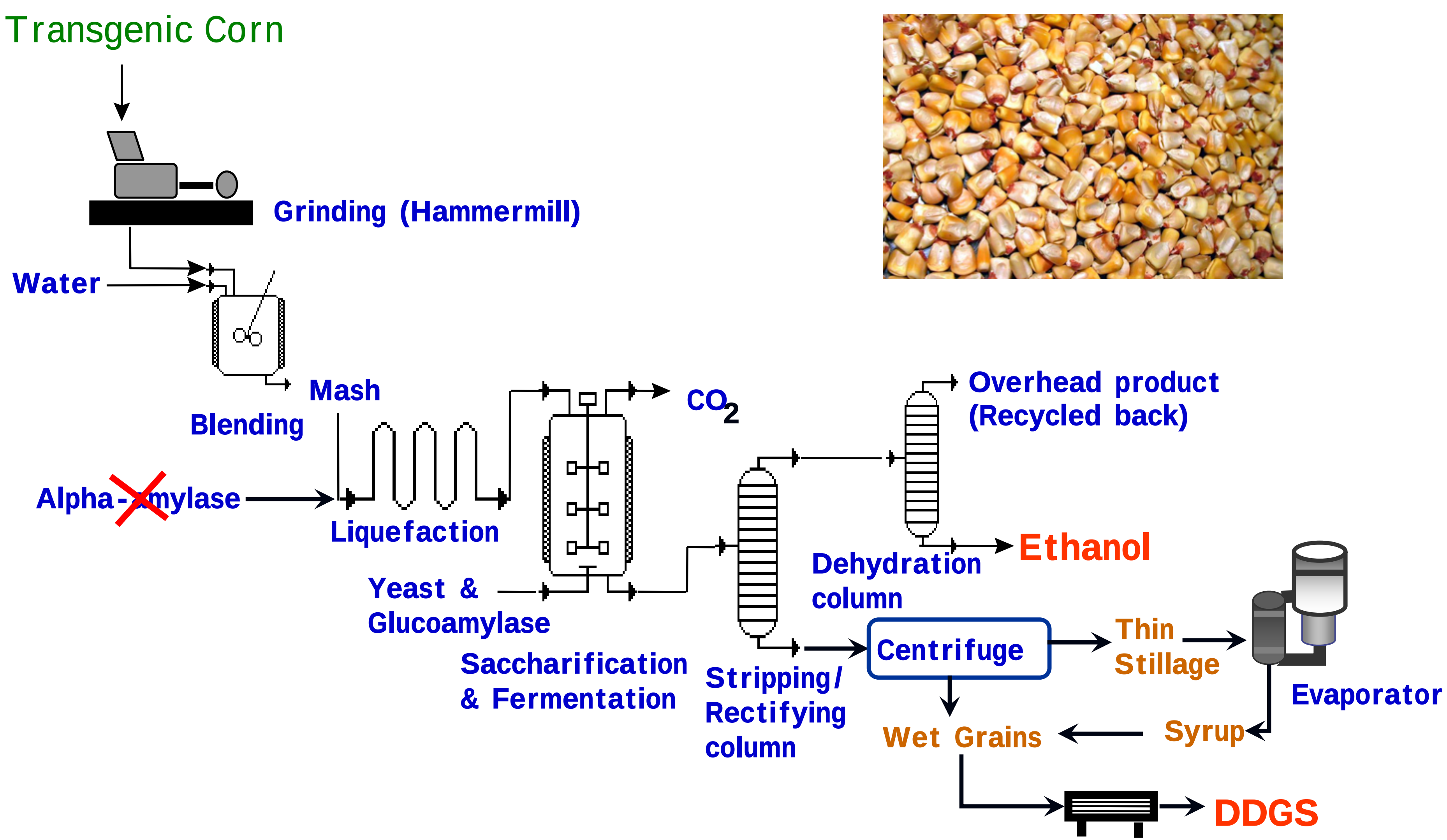
	Conv.	E-Mill	Soy Meal	CGM
Crude Prot. (%)	28.50	58.50	53.90	66.70
Crude Fat (%)	12.70	4.53	1.11	2.77
Ash (%)	3.61	3.24	----	----
Acid Det. Fiber (%)	10.8	2.03	5.95	6.88

Singh, V., Johnston, D.B., Naidu, K., Rausch, K.D., Belyea, R.L. and Tumbleson, M.E. 2005. Comparison of modified dry grind corn processes for fermentation characteristics and DDGS composition. Cereal Chem. 82:187-190.

Emerging Technologies in Dry Grind Ethanol Production:

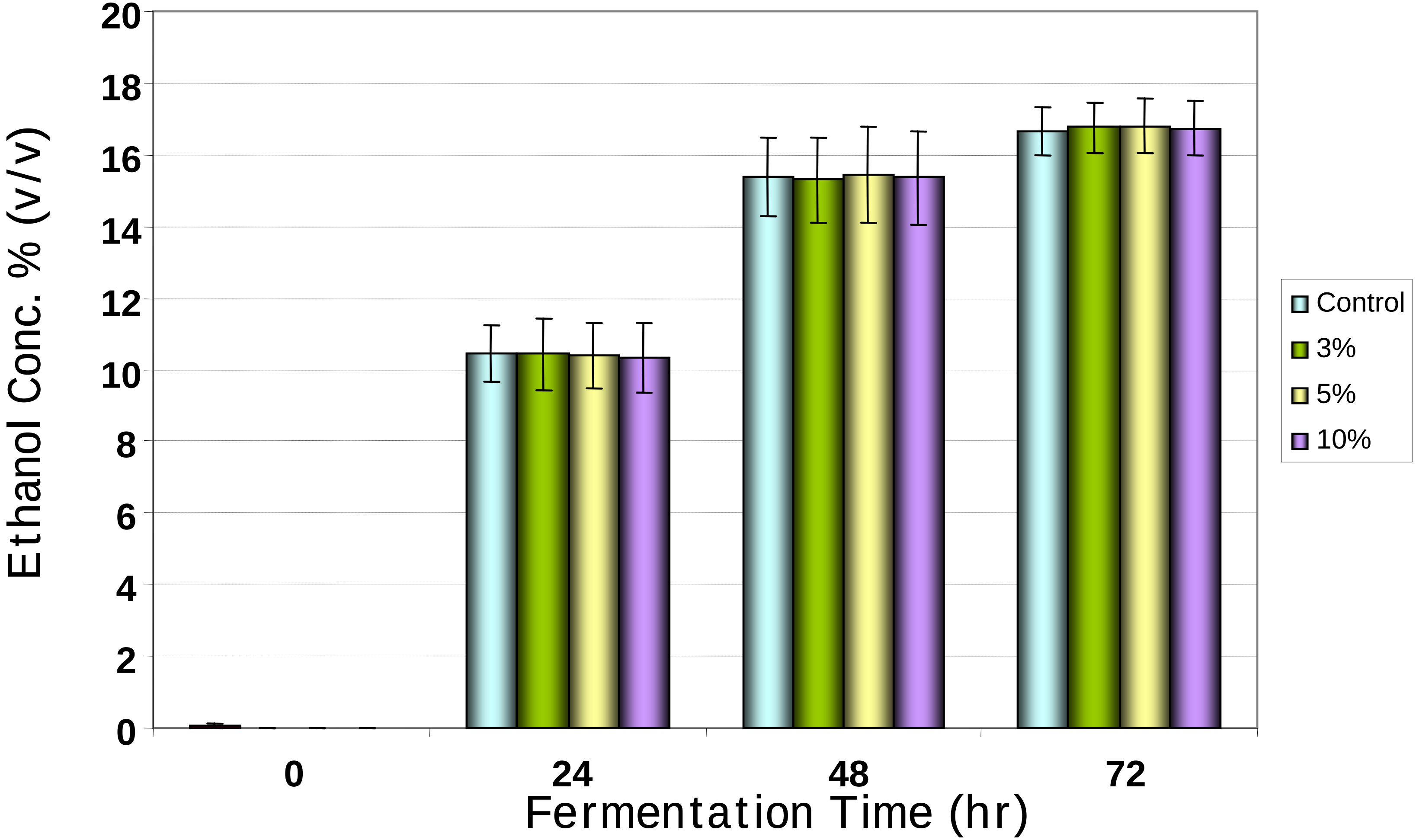
Development of New Corn

Transgenic Corn for Dry Grind Process



500 ml Fermentations

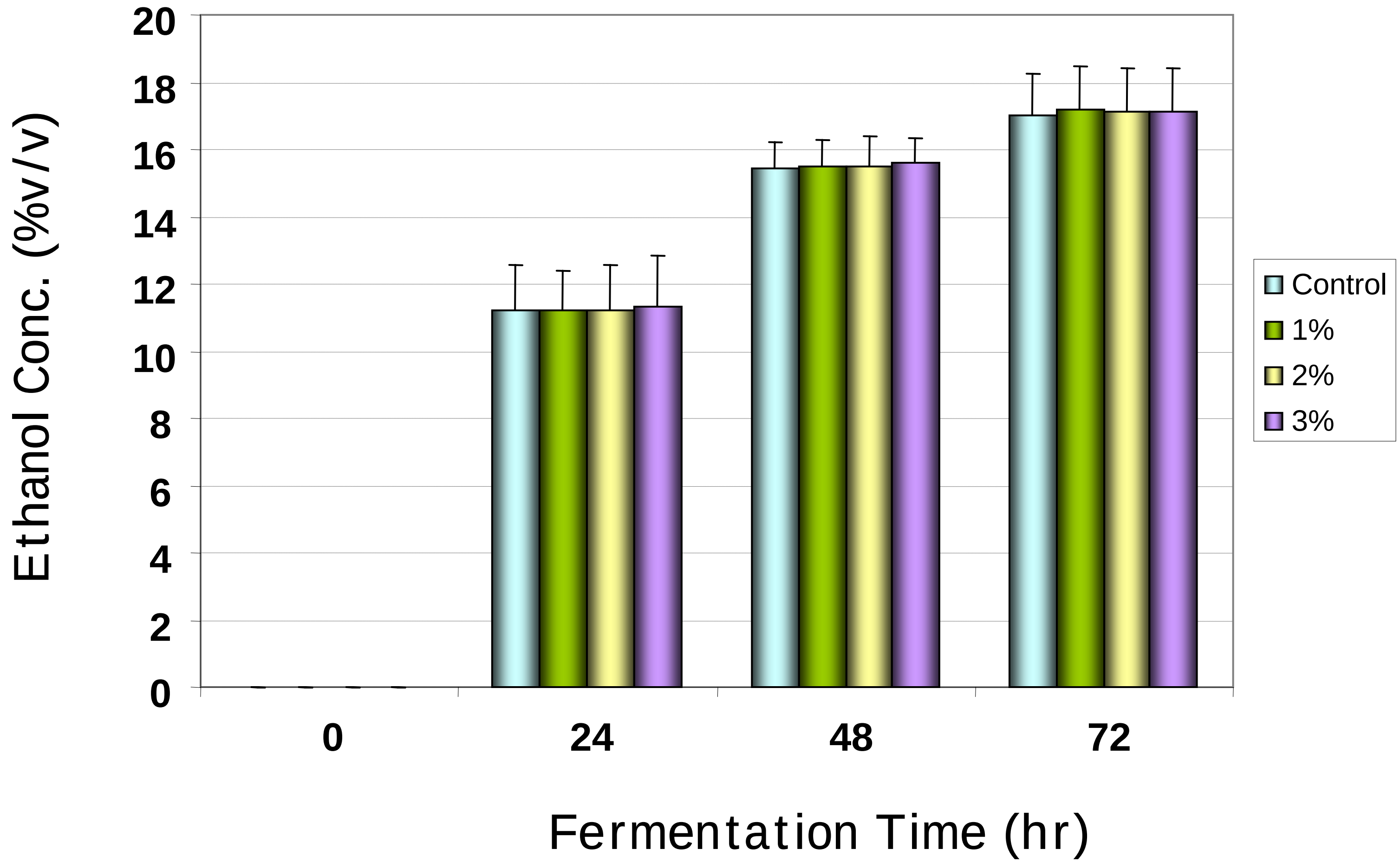
Control vs 3, 5 and 10% amylase corn addition



Singh, V, Batie, C.J., Aux, G.W., Rausch, K.D. and Miller, C. 2006. Dry grind processing of corn with endogenous liquefaction enzymes. Cereal Chem. 83:317-320.

500 ml Fermentations

Control vs 1, 2 and 3% amylase corn addition



Singh, V, Batie, C.J., Aux, G.W., Rausch, K.D. and Miller, C. 2006. Dry grind processing of corn with endogenous liquefaction enzymes. Cereal Chem. 83:317-320.

DDGS Composition

Components	3% amylase corn addition	Control Treatment
Crude Protein (%)	26.1 ± 0.2	25.8 ± 0.1
Crude Fat (%)	14.1 ± 0.1	13.6 ± 0.2
Crude Fiber (%)	6.6 ± 0.1	6.8 ± 0.1
Ash (%)	3.78 ± 0.1	3.35 ± 0.1

No significant difference in composition of DDGS for 3% amylase corn addition and control treatment

Singh, V. and Graeber, J.V. 2005. Effect of corn hybrid variability and planting location on ethanol yields. Trans. ASAE 48:709-714

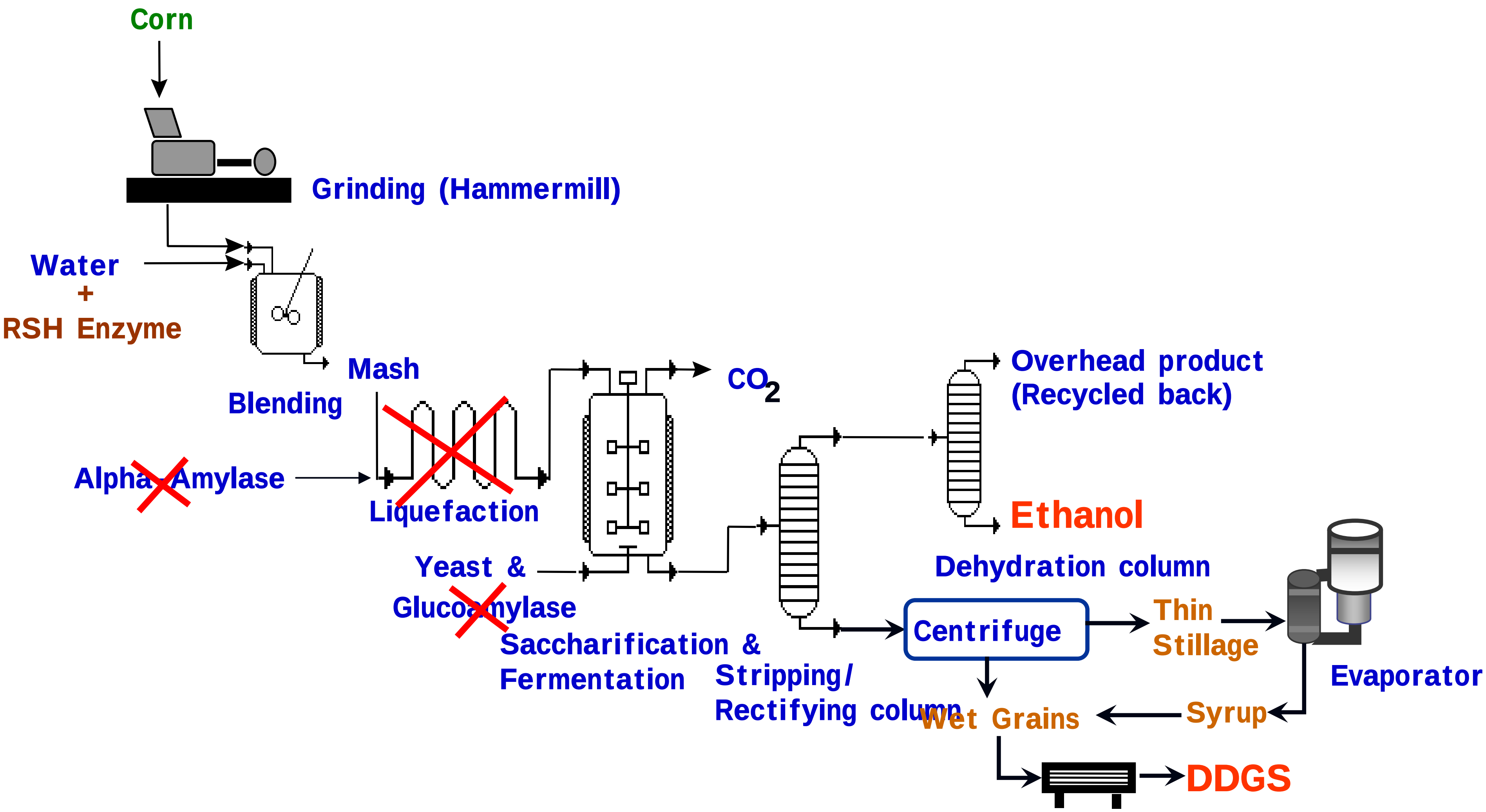
Feedstock Development: Transgenic Corn

- Reduces requirement of exogenous alpha amylase
- Only 3% amylase corn addition is required with dent corn for complete liquefaction
- No differences in DDGS composition between 3% amylase corn treatment and conventional treatment

Emerging Technologies in Dry Grind Ethanol Production:

Raw Starch Hydrolyzing Enzymes

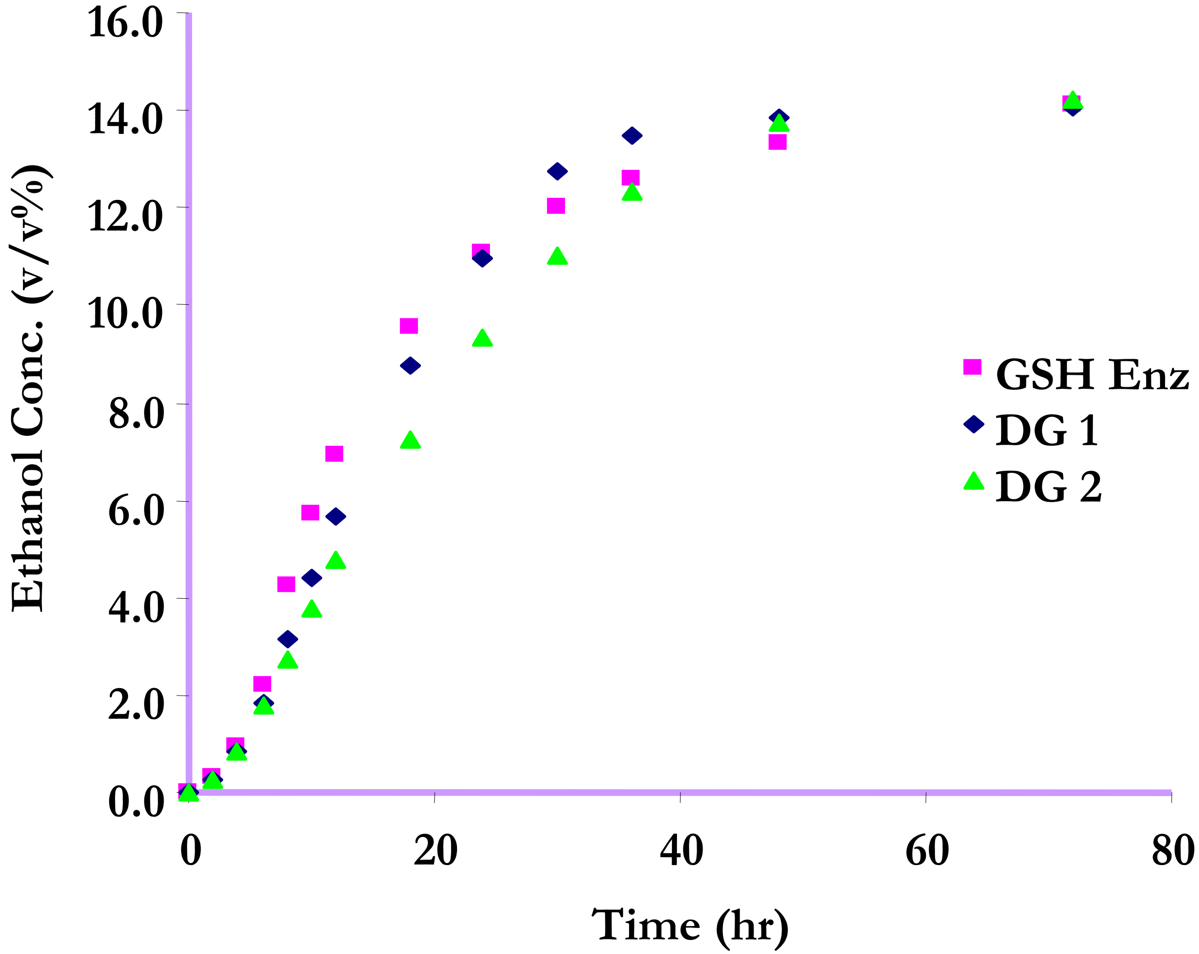
Raw Starch Hydrolyzing Enzymes



Granular Starch Hydrolyzing (GSH) Enzymes

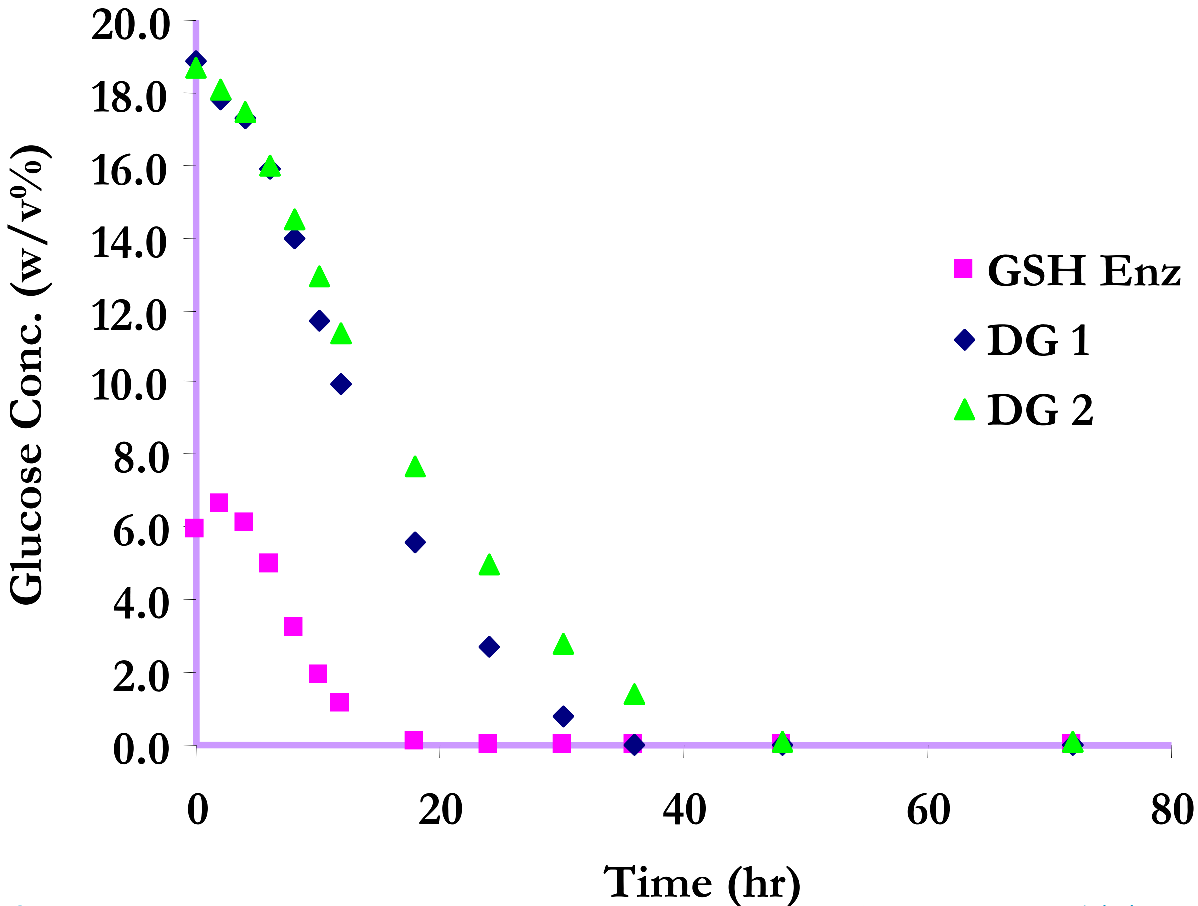
- These enzymes have high granular starch (raw starch or native starch) hydrolyzing activity
- Can Liquefy and saccharify starch into glucose at low temperature (< 48°C)
  - Stargen 001, Genencor International
  - BPX, Novozymes NA

Results: Ethanol Concentration



Wang, P., Singh, V., Xue, H., Johnston, D.B., Rausch, K.D. and Tumbleson, M.E. 2006. Comparison of raw starch hydrolyzing enzyme with conventional liquefaction and saccharification enzymes in dry grind corn processing. Cereal Chem. 84(1):10-14.

Results: Glucose Concentration



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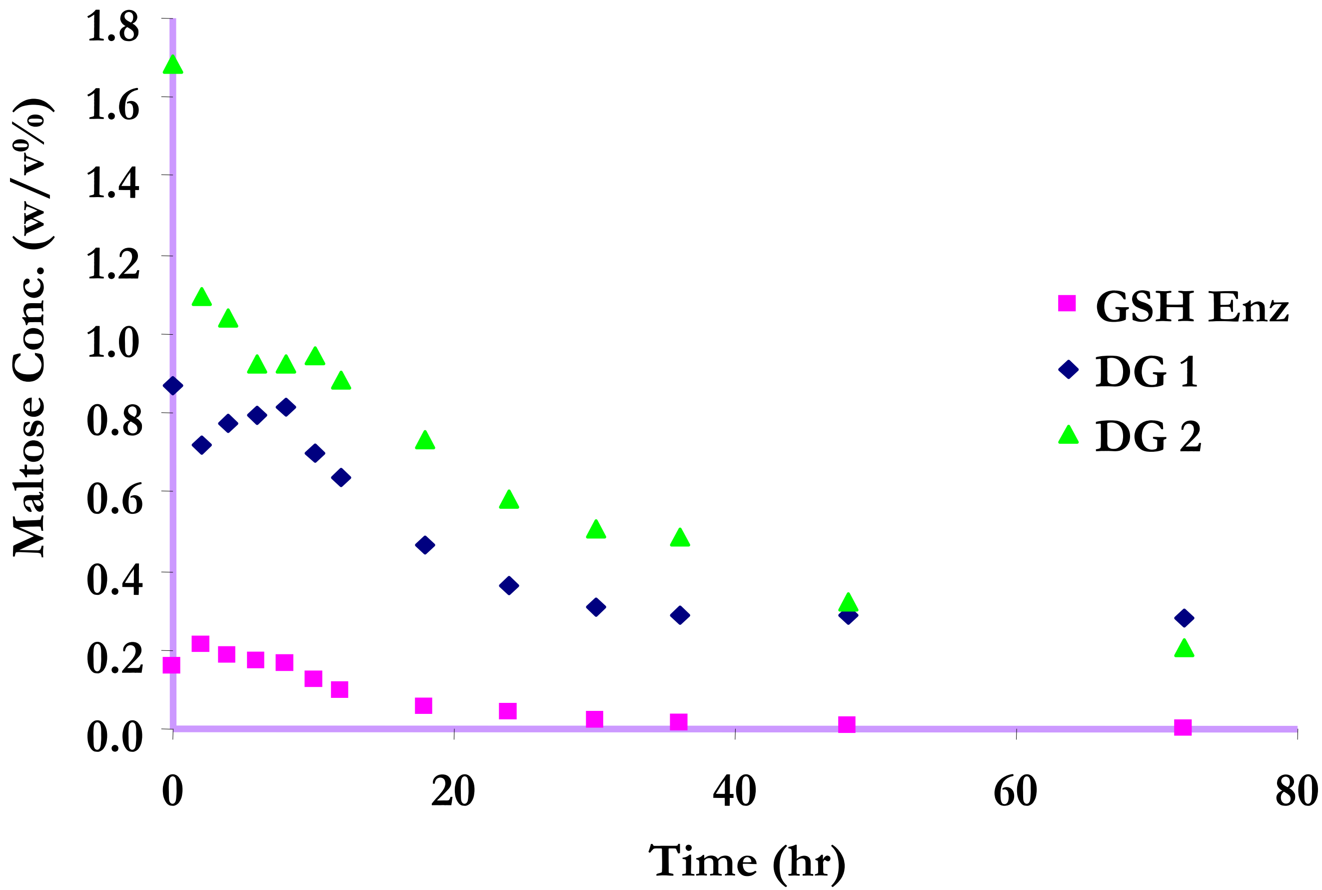
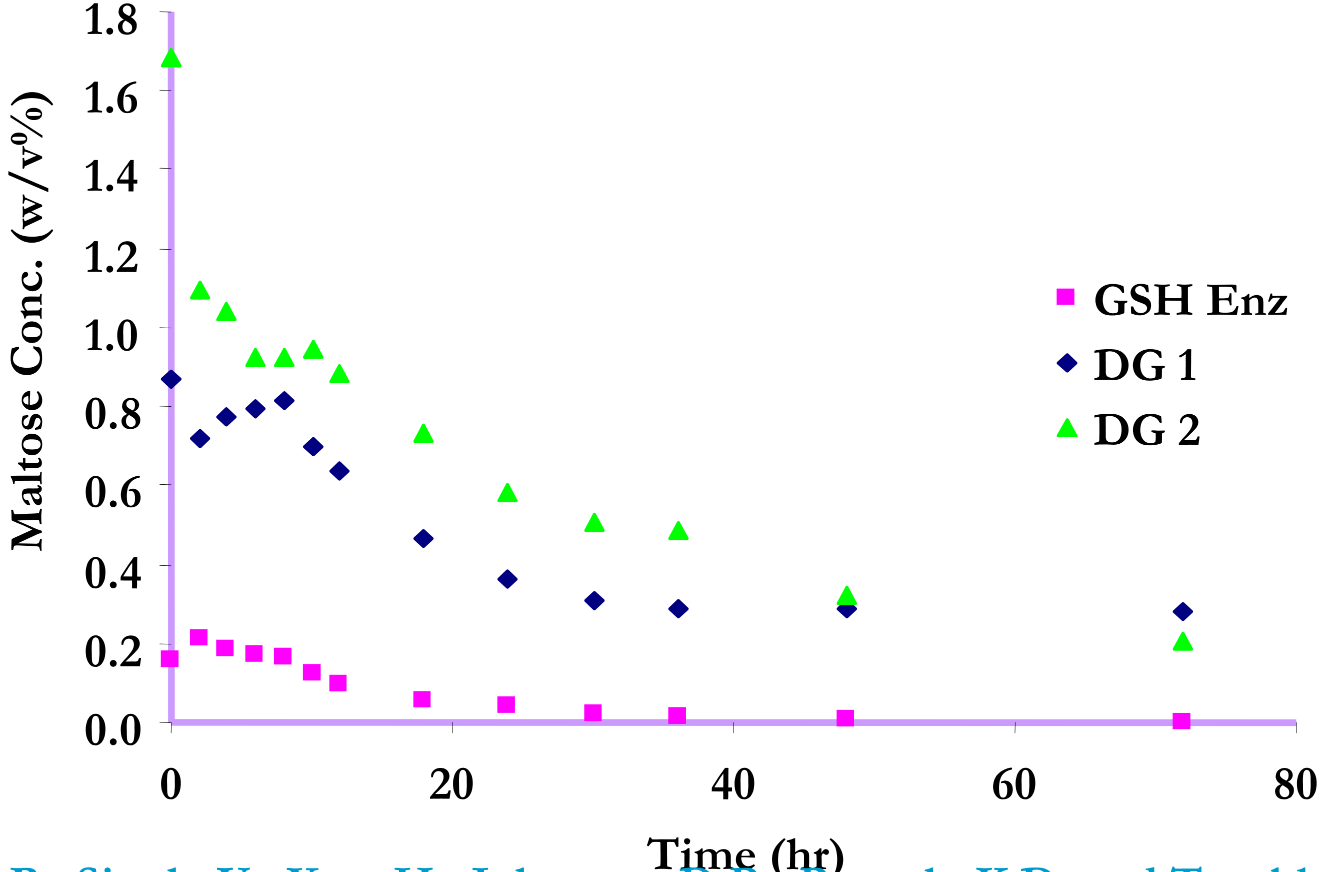
Results: Maltose Concentration



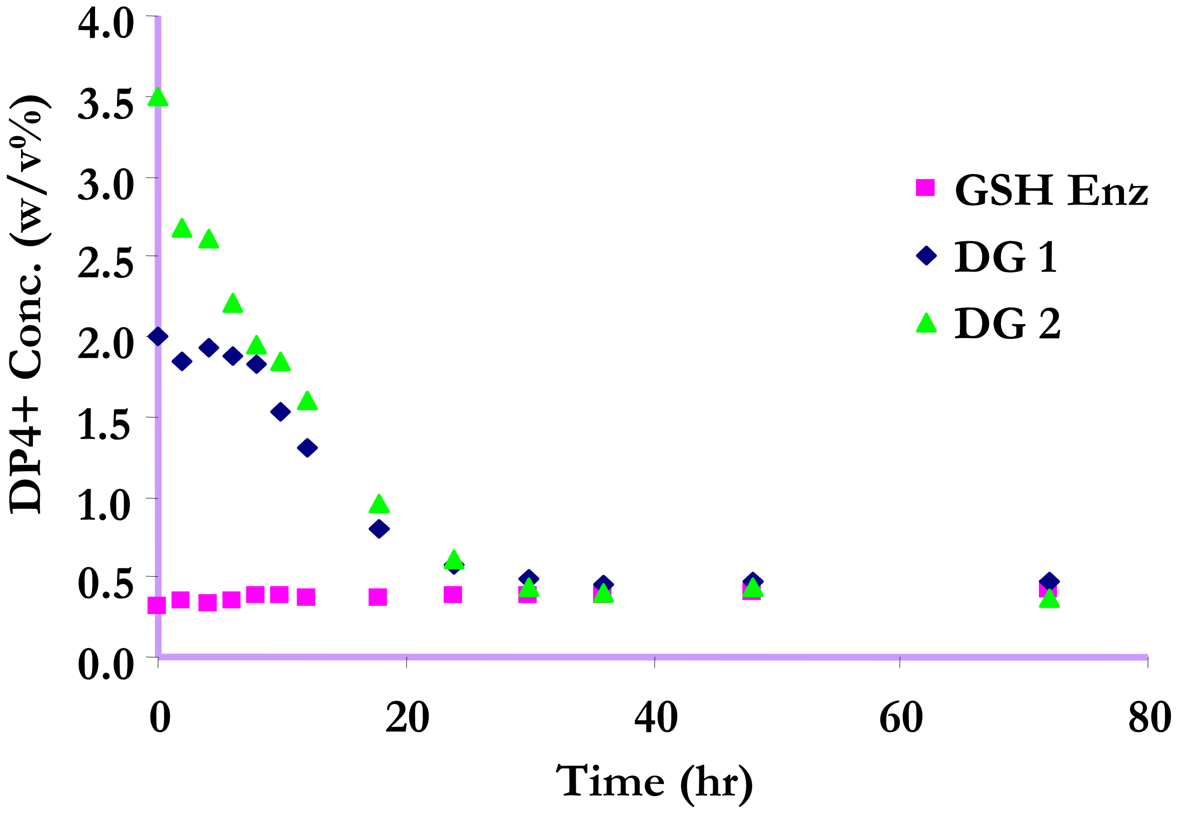
Wang, P., Singh, V., Xue, H., Johnston, D.B., Rausch, K.D. and Tumbleson, M.E. 2006. Comparison of raw starch hydrolyzing enzyme with conventional liquefaction and saccharification enzymes in dry grind corn processing. Cereal Chem. 84(1):10-14.

Results: Maltotriose Concentration



Wang, P., Singh, V., Xue, H., Johnston, D.B., Rausch, K.D. and Tumbleson, M.E. 2006. Comparison of raw starch hydrolyzing enzyme with conventional liquefaction and saccharification enzymes in dry grind corn processing. Cereal Chem. 84(1):10-14.

Results: DP4+ Concentration



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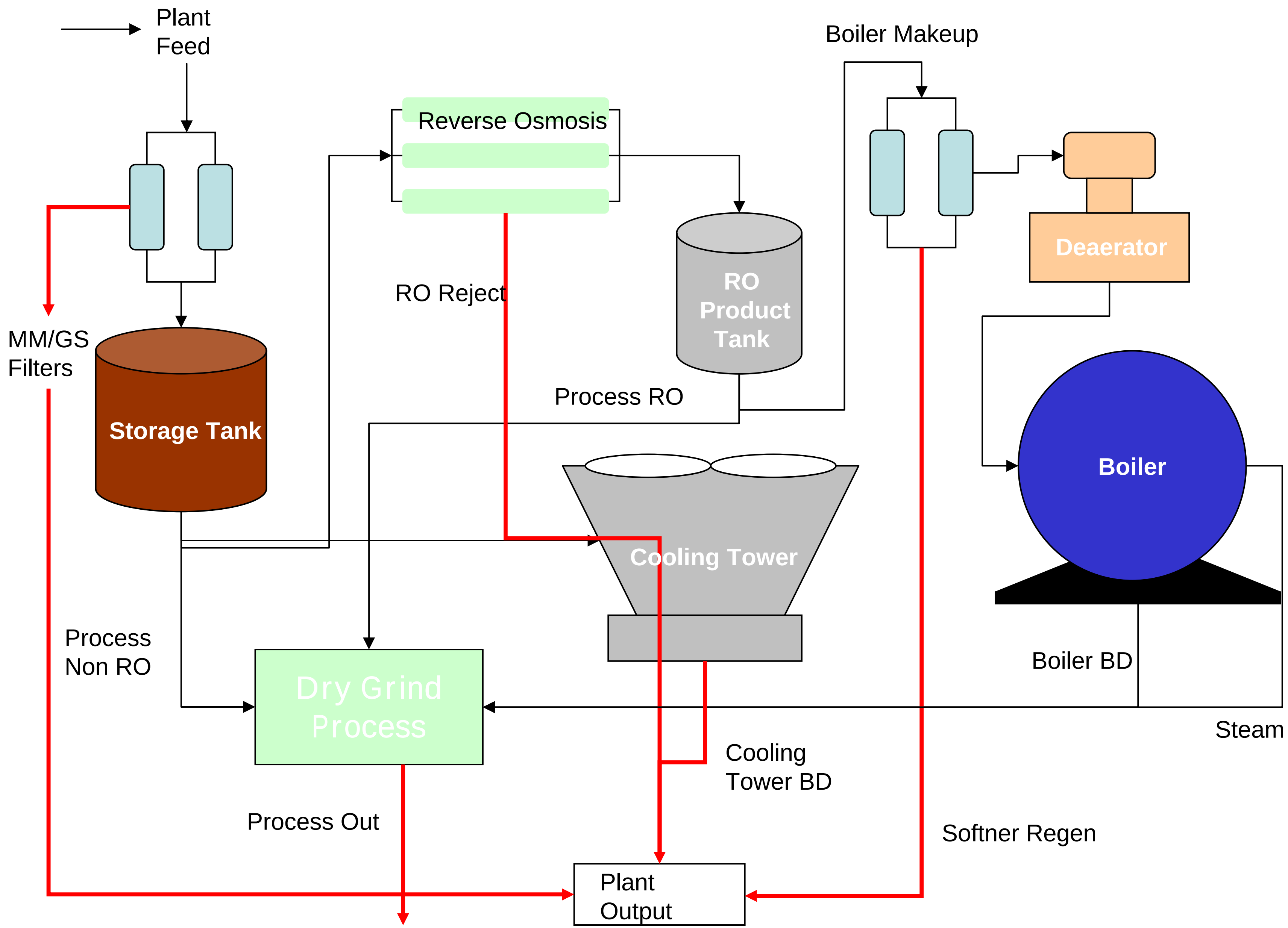
Granular Starch Hydrolyzing Enzymes

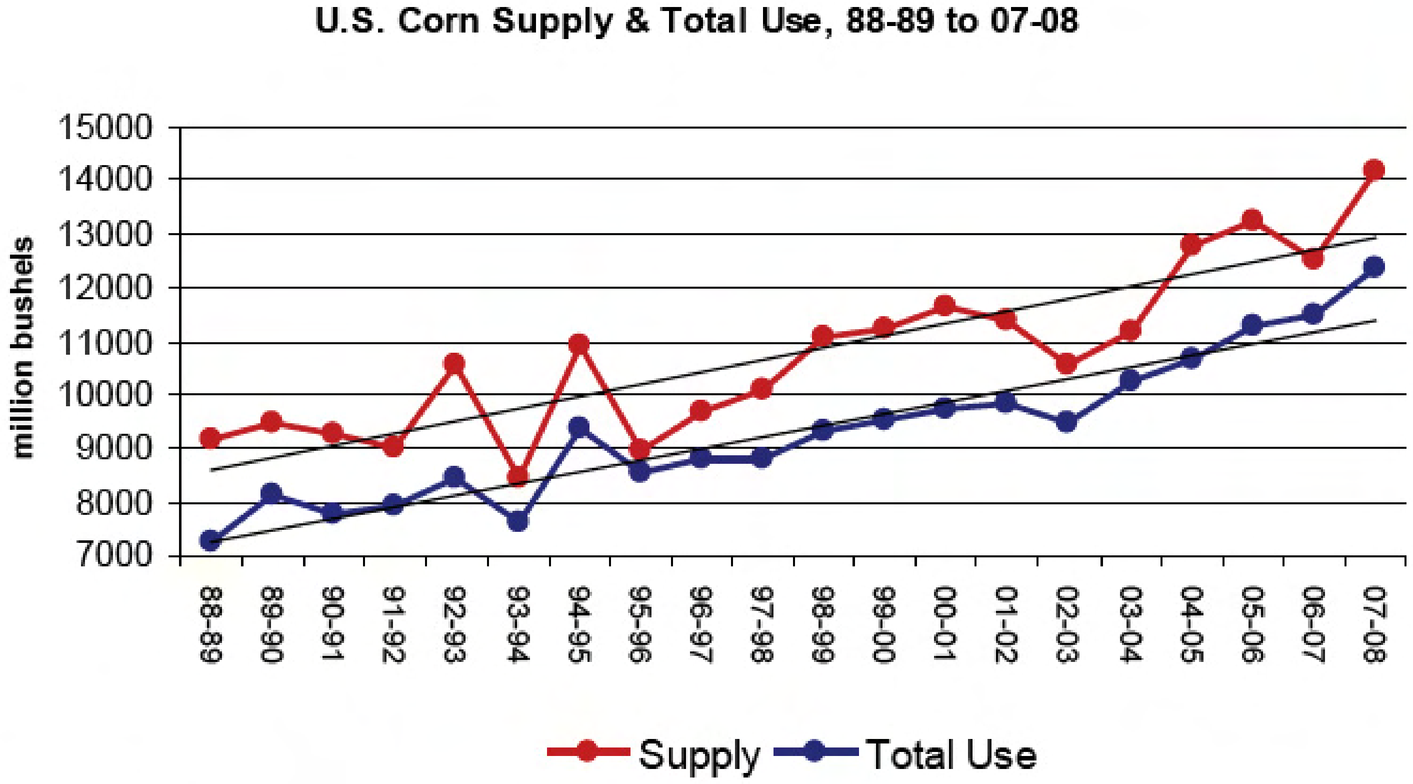
- Final ethanol yield with GSH enzymes is comparable to conventional enzymes
- Glucose, maltose and maltotriose concentrations are consistently low with GSH enzymes throughout fermentation
- GSH enzymes work at same temperature conditions as conventional SSF
  - With GSH enzymes simultaneous liquefaction, saccharification and fermentation can be conducted

Water Use in Dry Grind Ethanol Plant



Regenerative Thermal Oxidizer

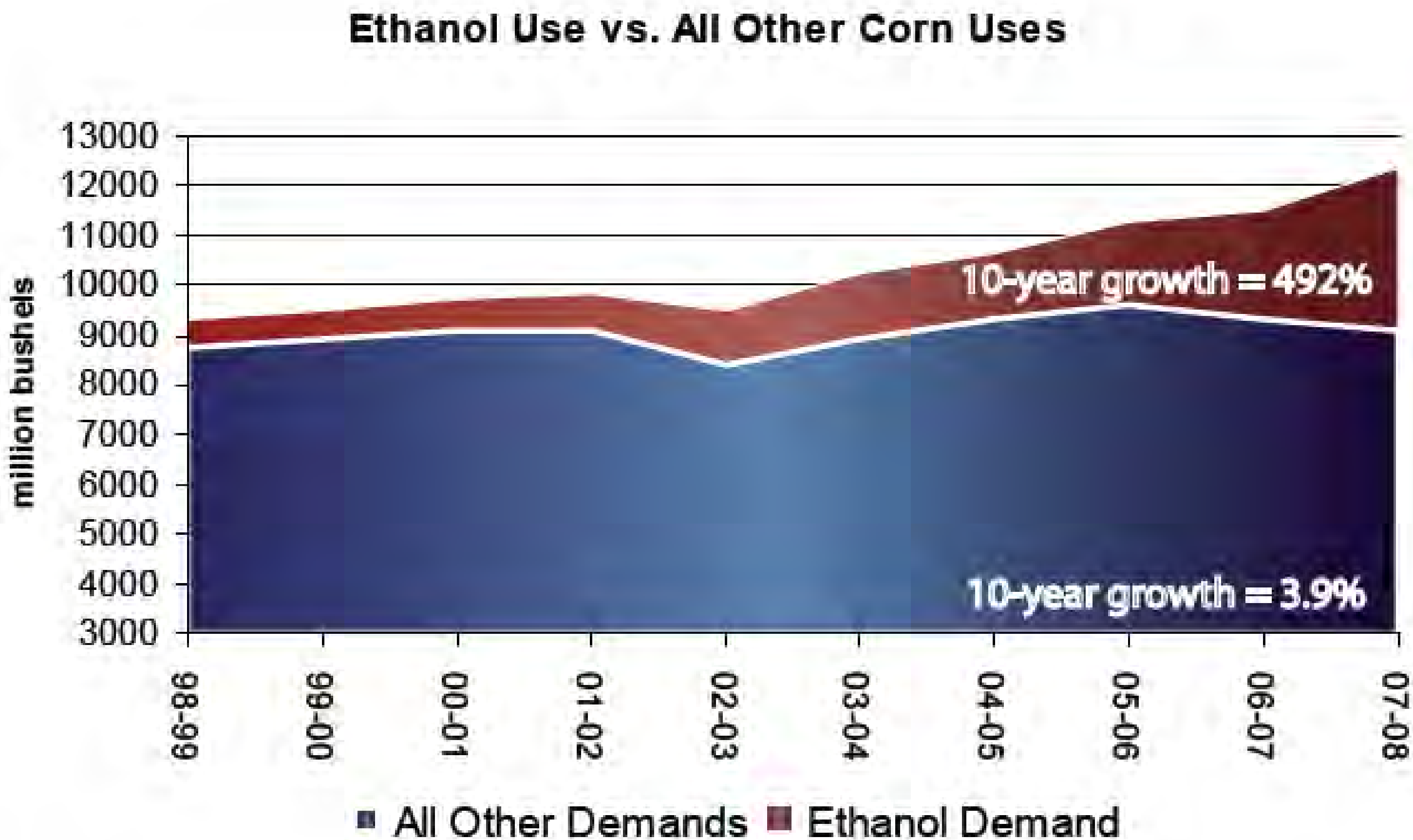
Food Versus Fuel



Source: USDA, ERS; ProExporter Network

Note: 07-08 is based on ProExporter Network projections

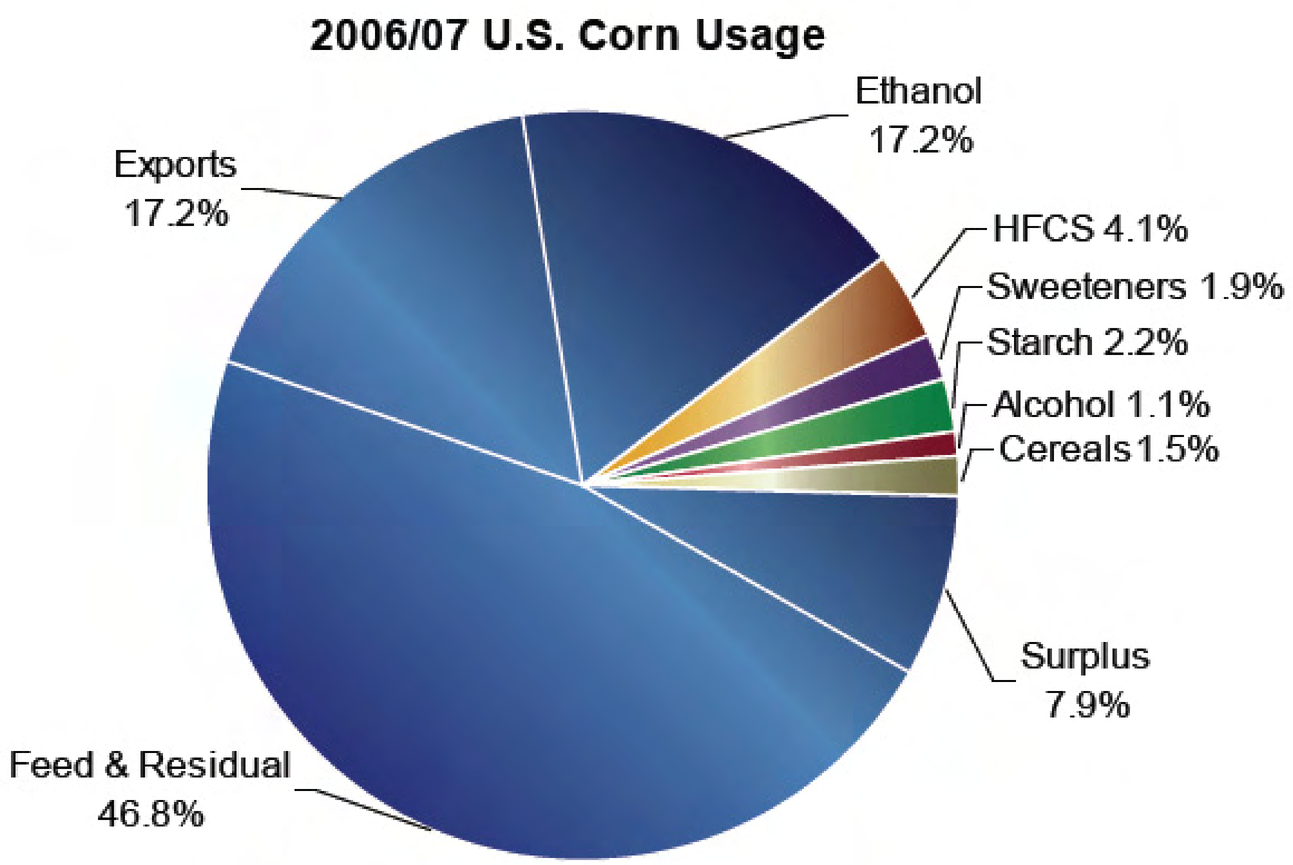
Food Versus Fuel



Source: USDA, ERS; ProExporter Network

Note: 07-08 Demand Figures from ProExporter Network; growth is absolute, 98-99 to 07-08

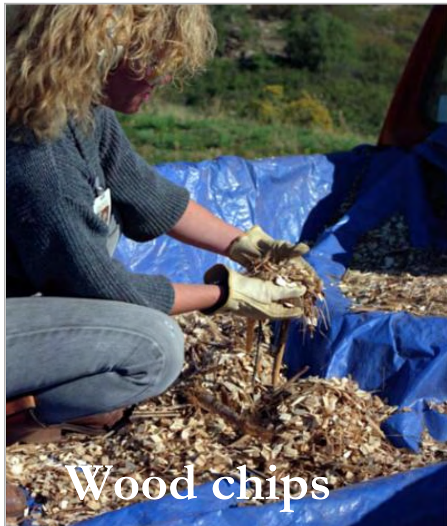
Food Versus Fuel

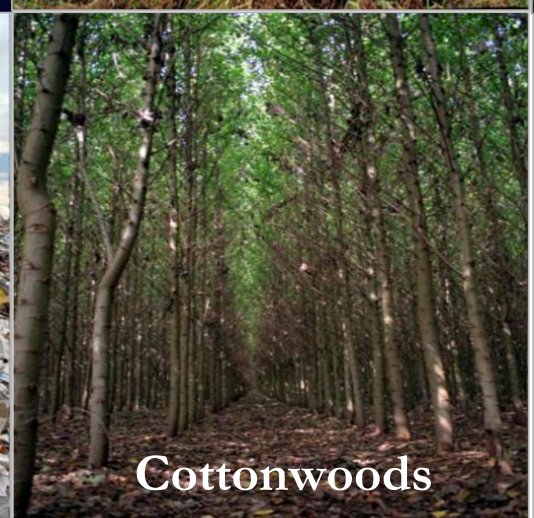


Source: USDA, ERS; Feed Outlook, June 13, 2007

Note: Percentages based on Total Supply

Future: Ethanol from Lignocellulosic Feedstocks





Thanks!