Developments of Corn for Dry Grind Corn Processing

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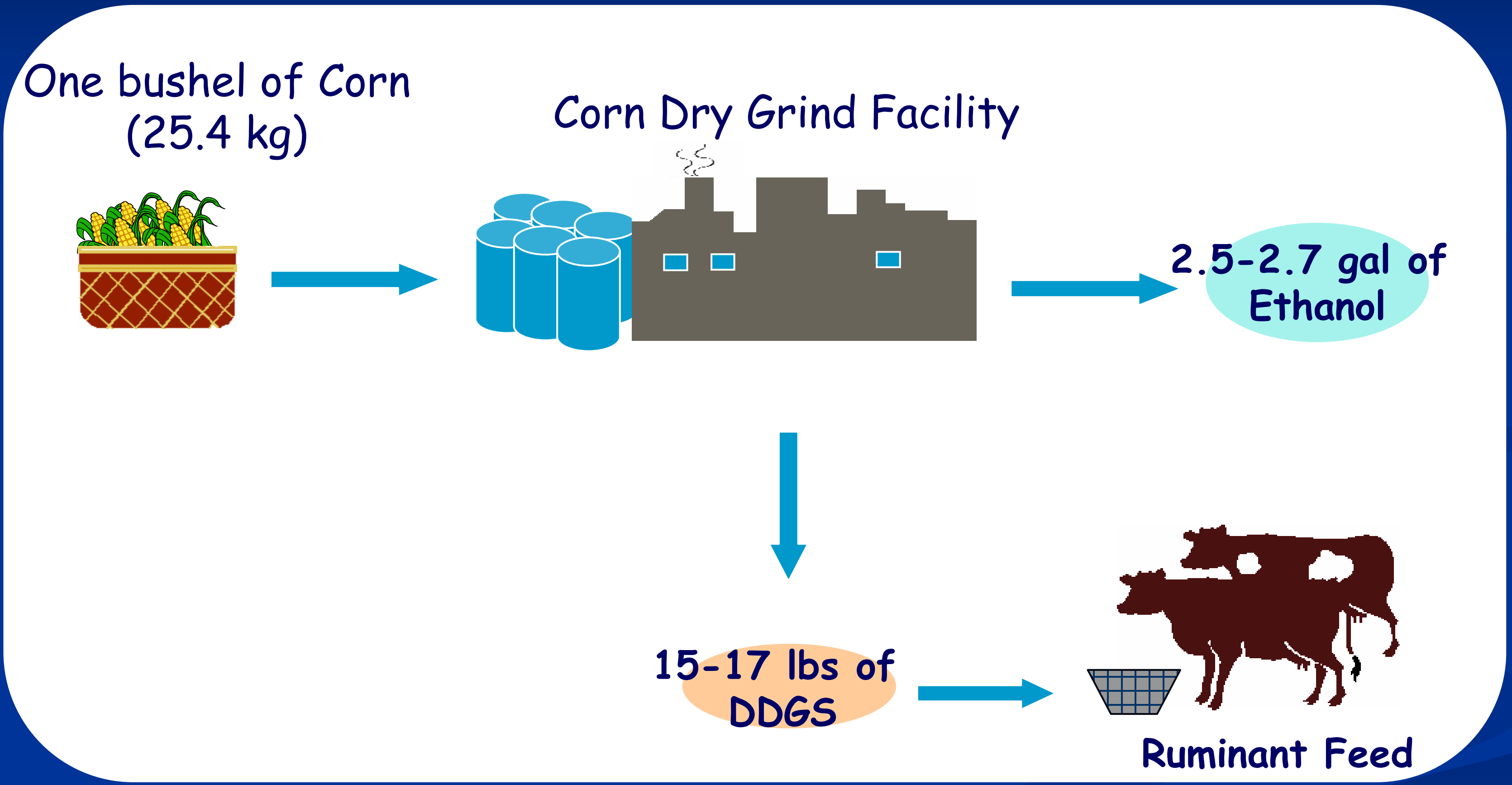
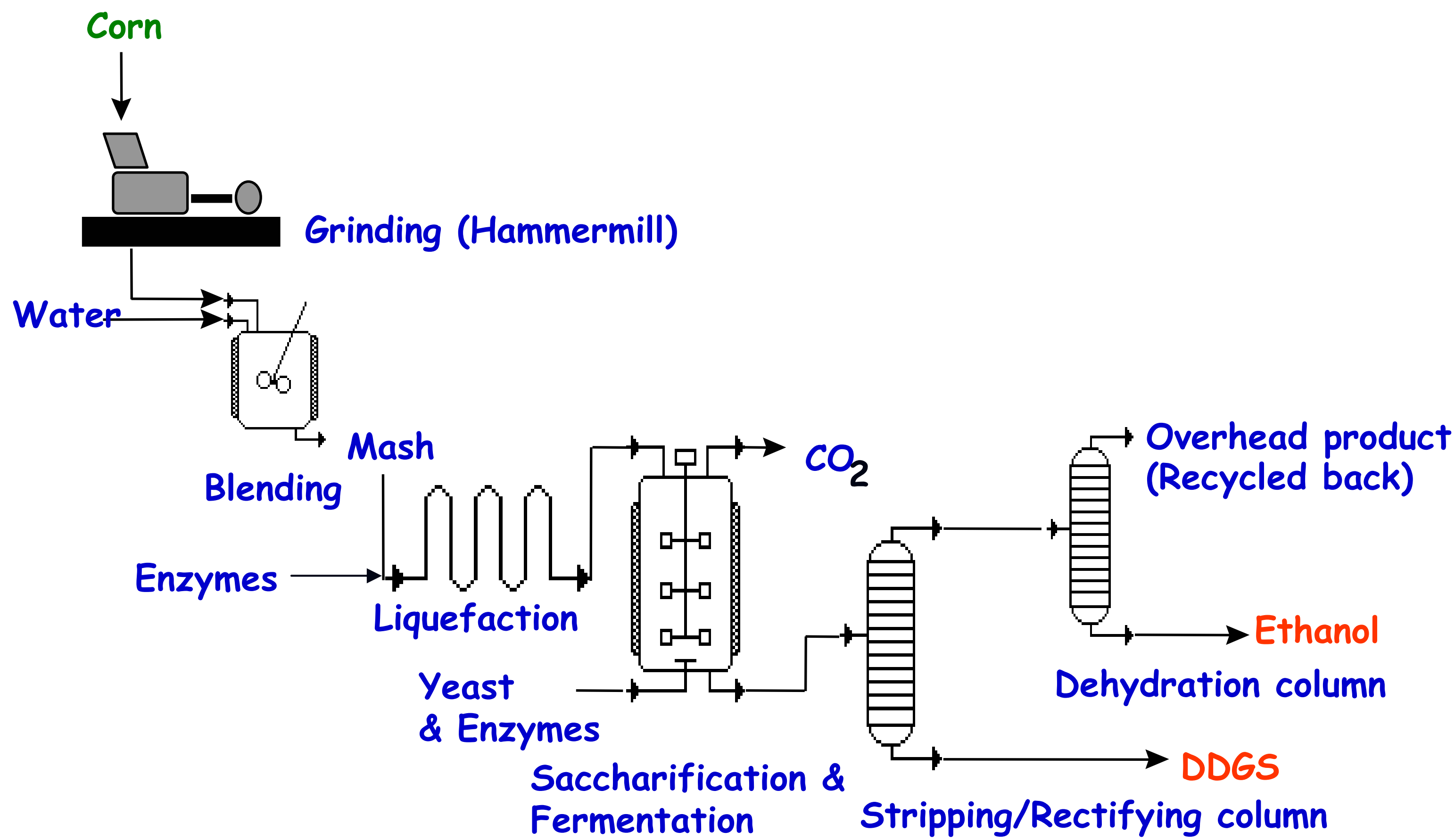
Presentation Outline

- Conventional Dry Grind Process
- Ethanol Production Capacity and Growth in Dry Grind Corn Processing Industry in US
- Development of Corn in Dry Grind Corn Processing
  - Effect of hybrid variability on dry grind corn process
  - High fermentable corn hybrids
  - Correlation between extractable starch and fermentable starch
  - Granular starch hydrolyzing enzymes
  - Corn hybrids with endogenous liquefaction enzymes
  - Corn hybrids for modified dry grind corn processes
- Conclusions

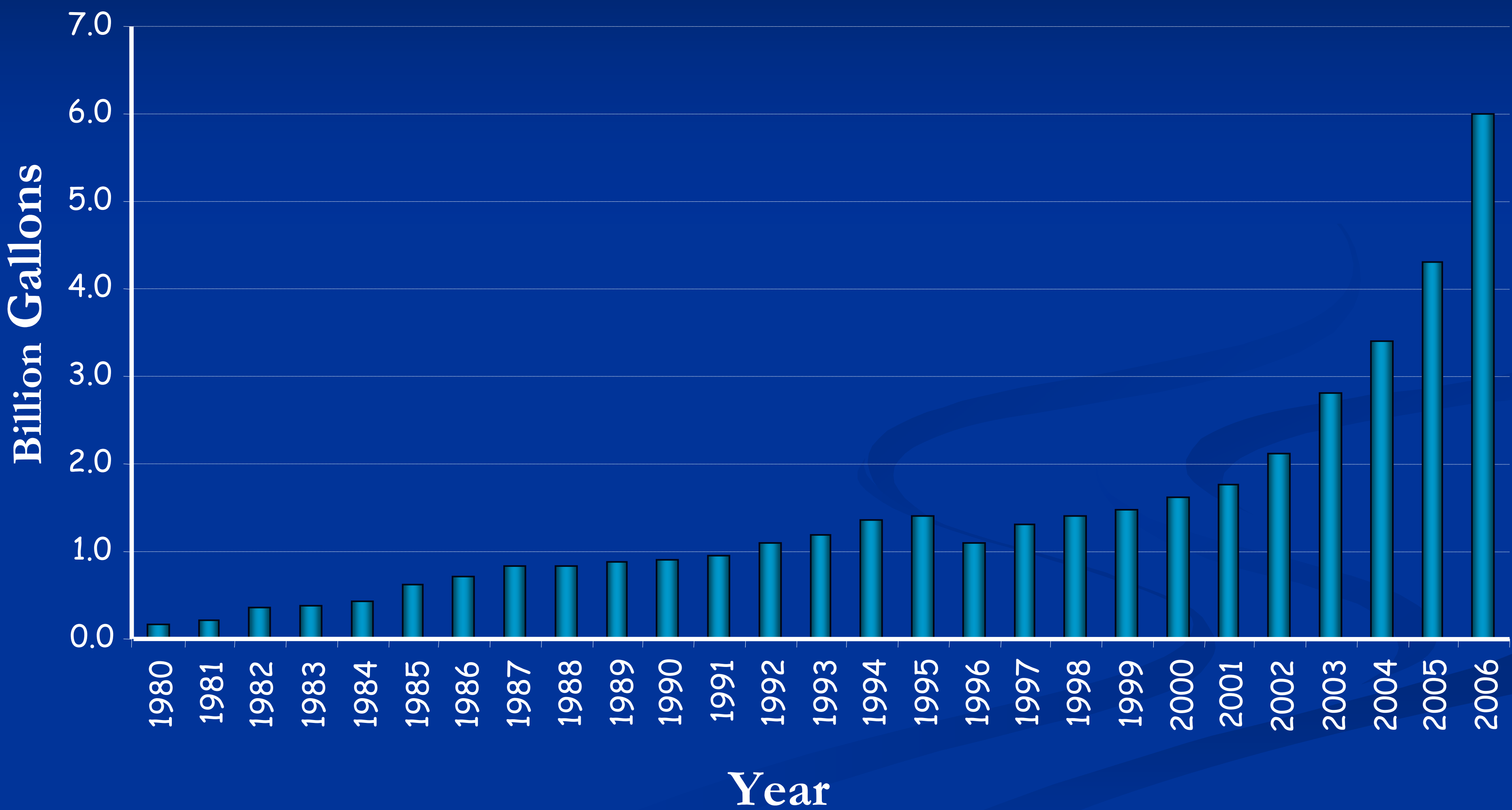
Dry Grind Process



Dry Grind Process



Ethanol Production in the US



Ethanol Production in the US

- Currently 4.3 billion gal of ethanol is produced in the US every year
- Estimates indicate that ethanol production in the US will increase to 6.0 billion gals/yr by 2006.
- Most of the increase in the ethanol capacity will come from new dry grind ethanol plants
  - Low capital cost for dry grind corn plants
  - Tax incentives from federal and state governments
  - Farmer co-ops

Developments of Corn for Dry Grind Process

- Hybrid Variability
- High fermentable corn hybrids
- Correlation between extractable starch and fermentable starch
- Corn hybrids with endogenous liquefaction enzymes
- Corn hybrids for modified dry grind corn processes

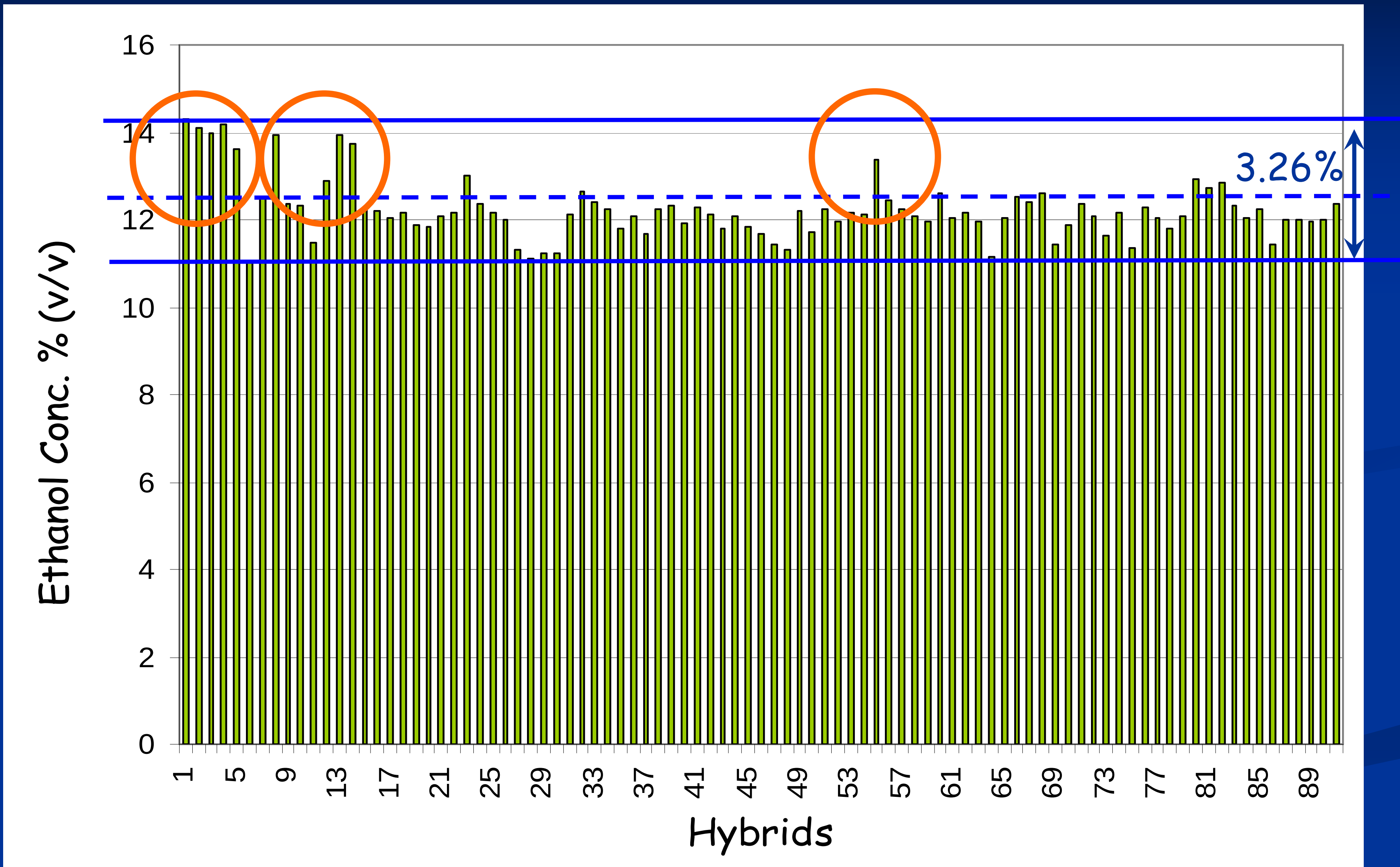
Hybrid Variability

- Hybrid variability in a dry grind corn facility is generally defined by two factors:
    1. Differences in fermentability
    2. Variation in the composition of DDGS

Effect of Hybrid Variability on Dry Grind Corn Process

- Final ethanol concentration in beer
- Coproduct quality
- Capital and Operating Cost
  - Process fluctuations
  - Maintenance

Extent of Hybrid Variability for Ethanol Production



Hybrid Specific Processing

- Limited number of elite line hybrids
  - good producer yields but with good ethanol yield, too

Identifying of Hybrids with High Fermentability

2004 Pioneer® brand hybrids for

Dry-Grind Ethanol

PIONEER Industry Select™ PROGRAM

HIGH TOTAL FERMENTABLES:

HYBRID	CRM ZONE	TRAIT	BASE GENETICS
37D03	95		37D03
37D25	95		37D25
38A24	95		38A24
38A25	95	YGCB	38A24
38P06	95	YGCB	38P05
38T27	95		38T27
38T28	95	YGCB	38T27
36N70	100		36N70
38A23	100	YGCB, CL	38A24
38A81*^	100	RR	38A24
38H67*	100		38H67
35D45	103		35D45
35P12	103		35P12
35P17	103	LL	35P12
35Y54	103		35Y54
35Y65	103		35Y65
36N18*^	103	RR	36N70
36N71	103	YGCB	36N70
36N72*^	103	HX1, LL	36N70
34B97	108		34B97
34G81	108		34G81
34G82	108	YGCB	34G81
34H31	108		34H31
34H32*	108	YGCB	34H31
34M94	108		34M94
34N16	108		34N16
34N43	108		34N43
34N44	108	YGCB	34N43
35P14^	108	YGCB, LL	35P12
35P15	108	YGCB, CL	35P12
35P80*^	108	RR	35P12
35Y55	108	YGCB	35Y54
35Y67*^	108	HX1, LL	35Y65
32D12	113		32D12
33B25*^	113	RR	33B50
33B50	113		33B50
33B51	113	YGCB	33B50
33B55*^	113	HX1, LL	33B50
33D31	113		33D31
33H05*	113		33H05
33J56	113		33J56
33J58	113	WX	33J56
33P34*^	113	RR	33P66
33P62*^	113	HX1, LL	33P66
33P66	113		33P66
33P67	113	YGCB	33P66
33P69	113	LL	33P66
33P71	113	CL	33P66
33R77	113		33R77
33R78*	113	YGCB	33R77
33R79	113	LL	33R77
34N42*^	113	HX1, LL	34N43
31B13	118	YGCB	3223
31G01	118	CL	31G98
31G98	118		31G98
31R88	118		31R88
32P75	118		32P75
32P76	118	YGCB	32P75
32R25	118		3223
32R42	118		32R42
32R43	118	YGCB	32R42

This is the North America HTF list of Pioneer® brand hybrids. Please check with your local Pioneer sales professional for availability of a more specific localized list of Pioneer HTF hybrids. The HTF designation is assigned to elite Pioneer brand hybrids that are above the mean based on data from over 15,000 Pionee samples from the past three years.

* = NEW

YGCB = Contains the YieldGard[1] Corn Borer gene. Pioneer® brand corn hybrids with the YieldGard Corn Borer gene.

[1] YieldGard and the YieldGard Corn Borer Design are trademarks used under license from Monsanto Company.

CL = Contains the CLEARFIELD[2] gene. Pionee brand corn hybrids with the CLEARFIELD gen

[2] Trademark of BASF.

HX1 = Contains Herculex[3] I insect protection. Pioneer® brand corn hybrids with Herculex I insect protection.

Herculex I insect protection technology by Dow AgroSciences and Pioneer Hi-Bred.

[3] Herculex is a trademark of Dow AgroSciences LLC.

LL = Contains the LibertyLink[4] gene. Pioneer® brand corn hybrids with the LibertyLink gene.

[4] Registered trademark of Bayer CropScience.

RR = Contains the Roundup Ready[5] gene. Pioneer® brand products with the Roundup Ready gene.

[5] Registered trademarks used under license from Monsanto Company.

Market Choices: Grain harvested from products that bear this mark is fully approved for food and feed use the United States and Japan, but is not approved in the European Union. You must find a market for this crop that will not ship this grain or processed products to Europe. Appropriate markets for th grain include: domestic feed use or grain handlers that specifically agree to accept this grain and handle it appropriately. For more information on your grain marke options, go to the American Seed Trade Association's website at www.amseed.org or call your seed supplier.

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Know Before You Grow™, an information service provided by National Corn Growers Association at www.ncga.com.

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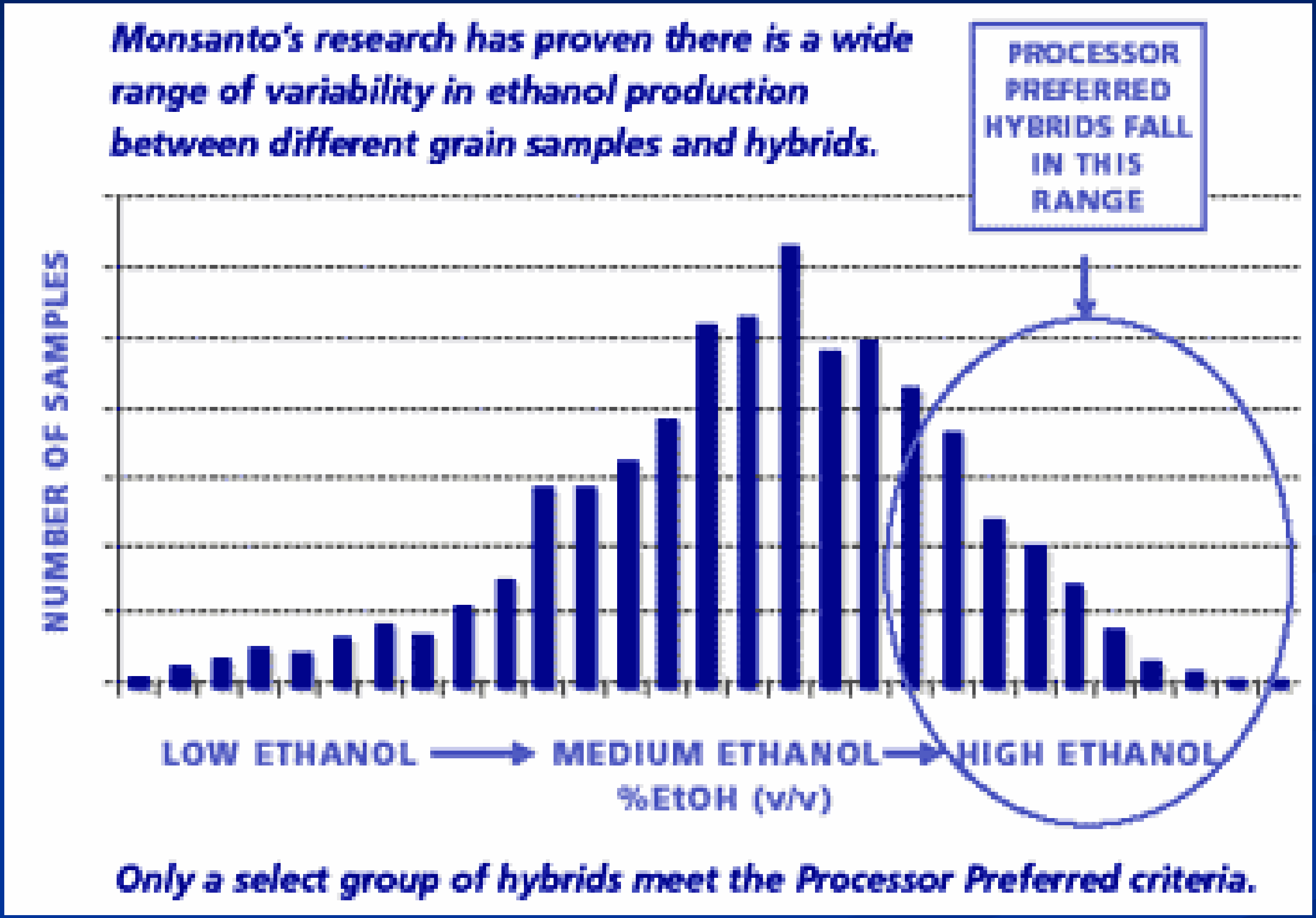
Identifying of Hybrids with High Fermentability



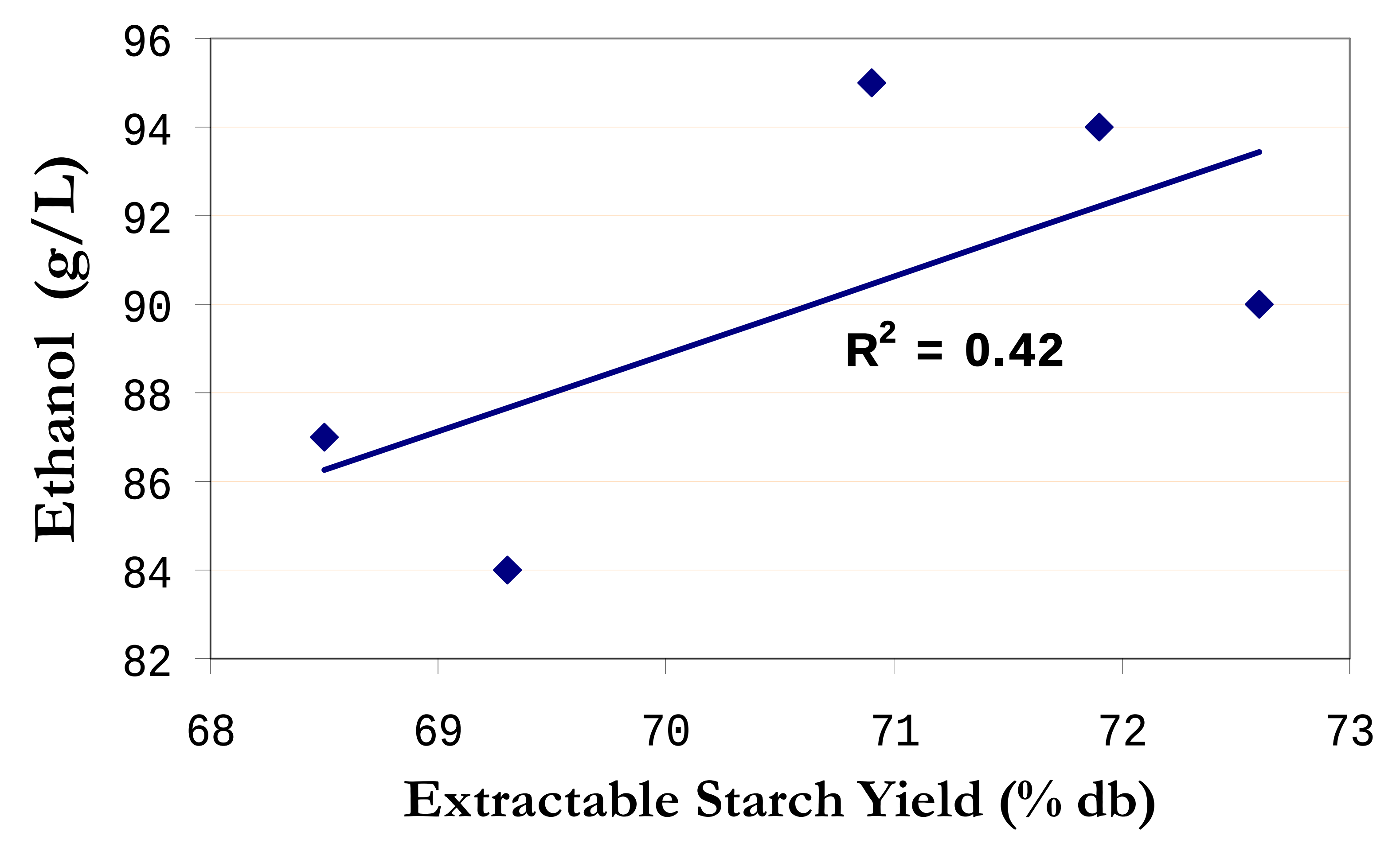
Source: http://www.monsanto.com/monsanto/us_ag/content/enhanced_value/pro_per/pro_per_corn/brochure.pdf

What Causes Hybrid Variability

- Variability due to genetics
  - Starch?
  - Protein?
  - Other constituents?
- Variability due to environment (phenotype)
  - Effect of location
  - Effect of crop year

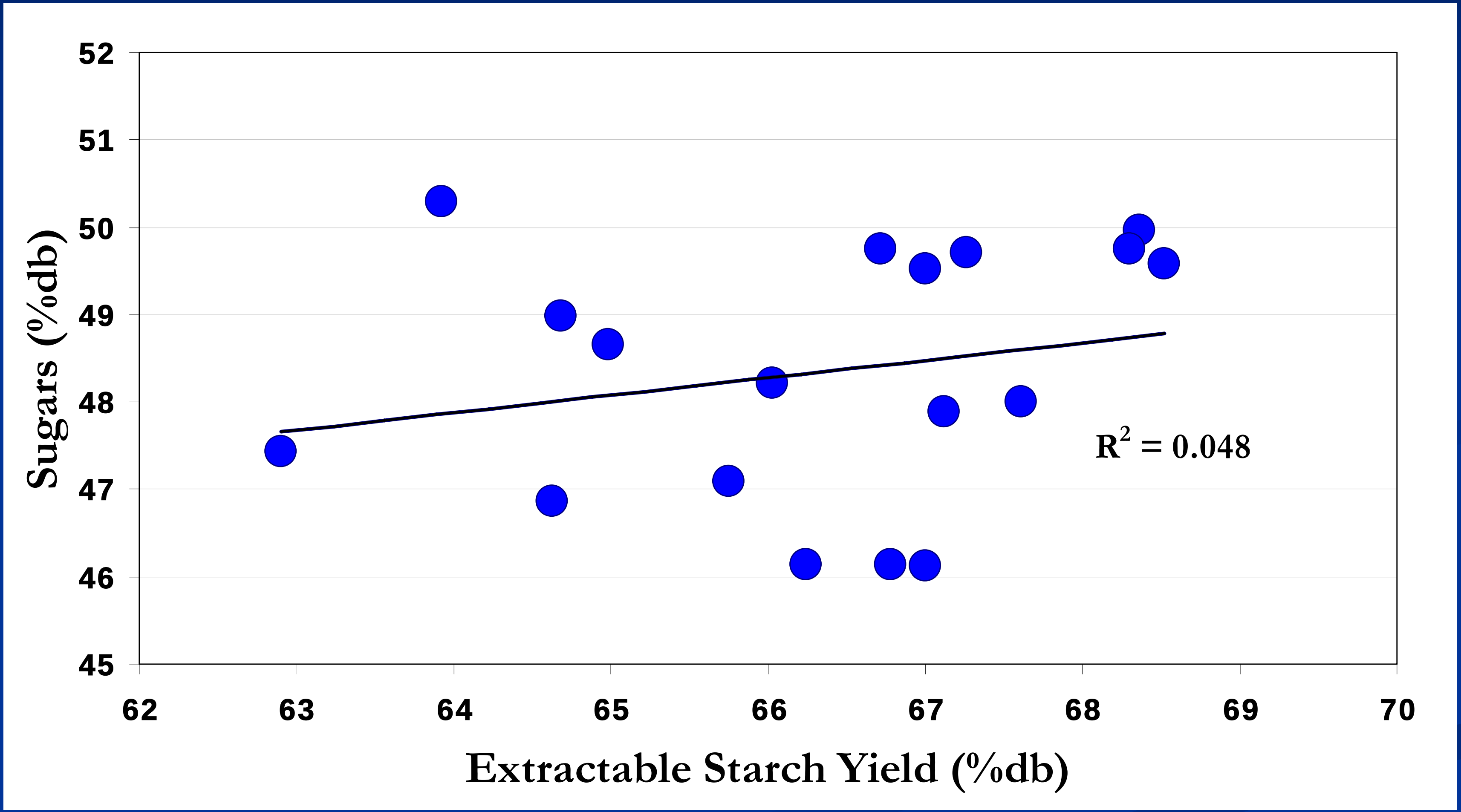
Correlation between Starch and Ethanol

Starch Yield and Ethanol
(Dien et al 2002)



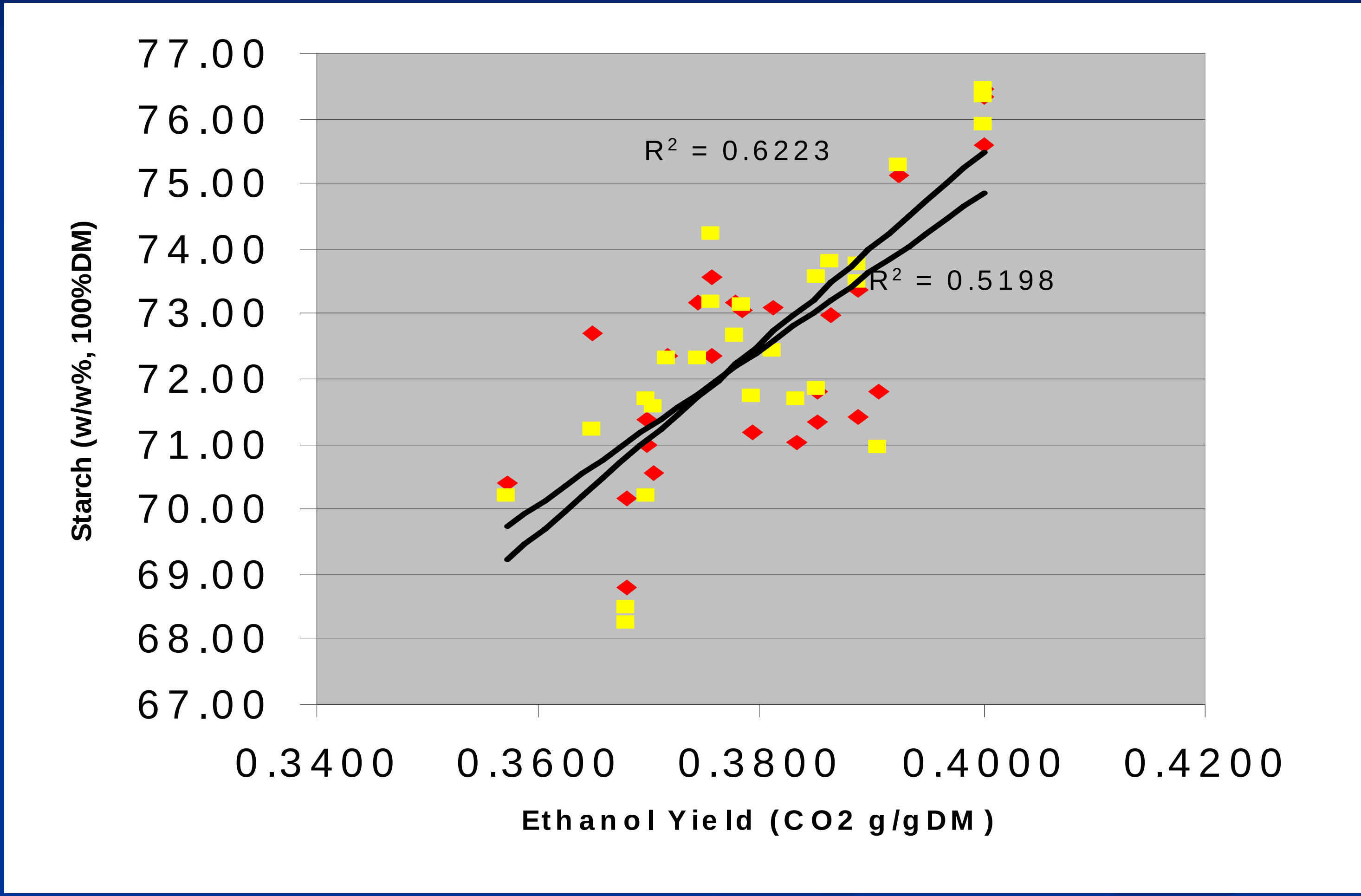
Dien, B.S., Bothast, R.J., Iten, L.B., Barrios, L. and Eckhoff, S.R. 2002. Fate of Bt protein and influence of corn hybrid on ethanol production. Cereal Chem. 79:582-585

Starch Yield and Sugars (Pruiett 2002)



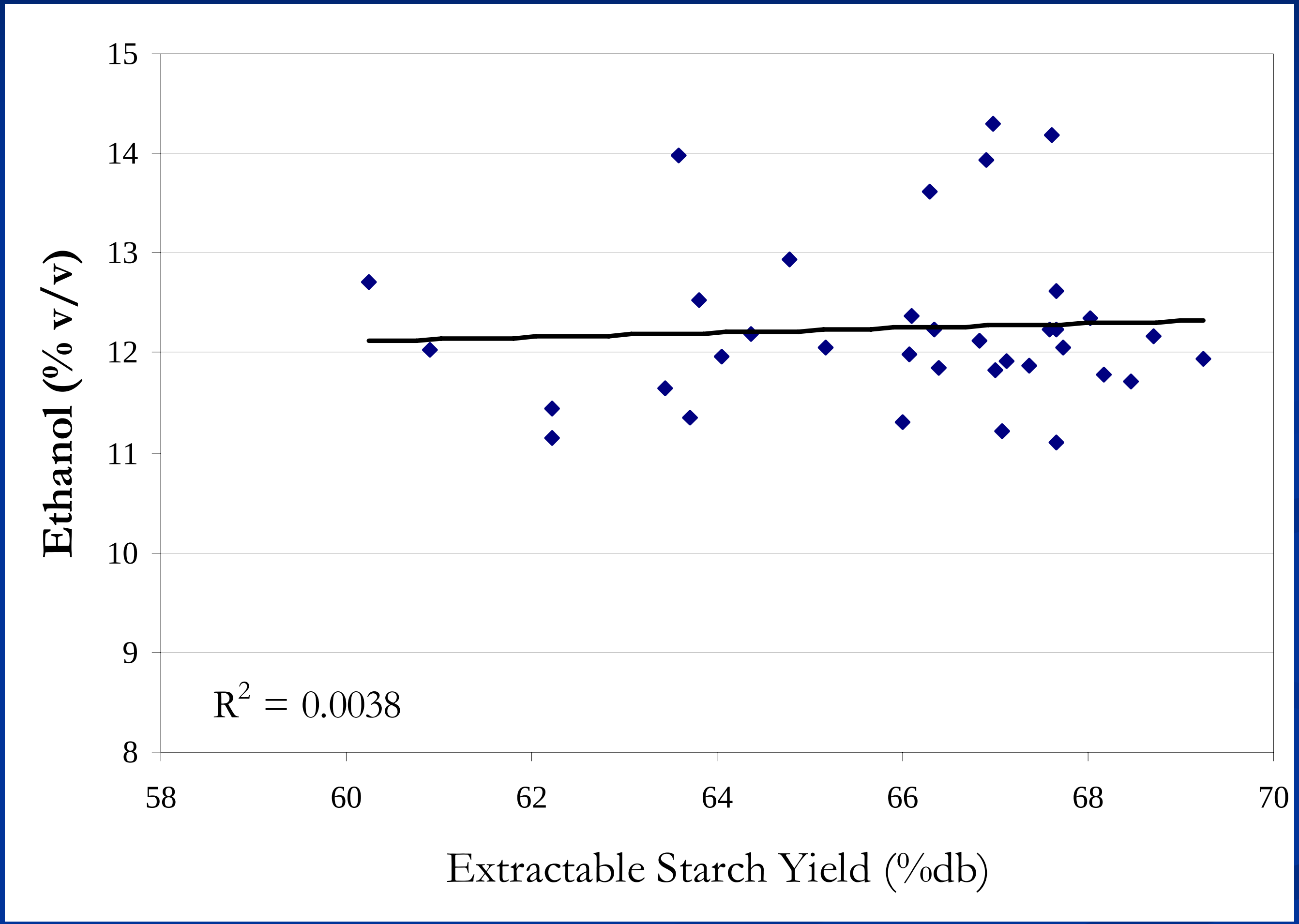
Pruiett, L. 2002. Unpublished Data. University of Illinois.

Starch Content and Ethanol Yield (Haefele et al 2004)



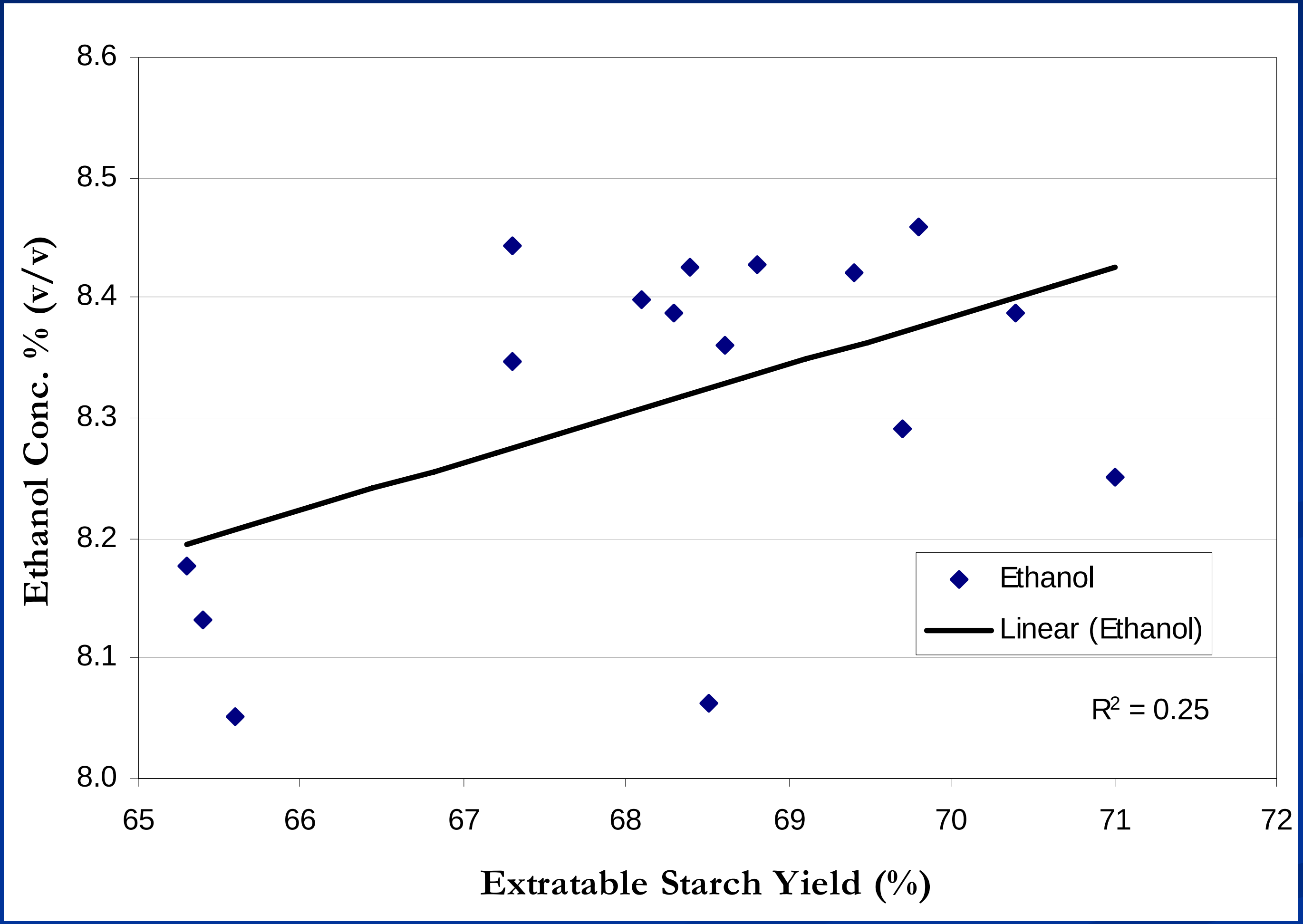
Haefele, D., Owens, F., O'Bryan, K. and Sevenich, D. 2004. Selection and optimization of corn hybrids for fuel ethanol production. 21 pp. Proc. Am. Seed Trade Assoc. 59th Annual Corn and Sorghum Research Conference, Chicago, IL.

Starch Yield and Ethanol Conc. (Singh and Graeber 2005)



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

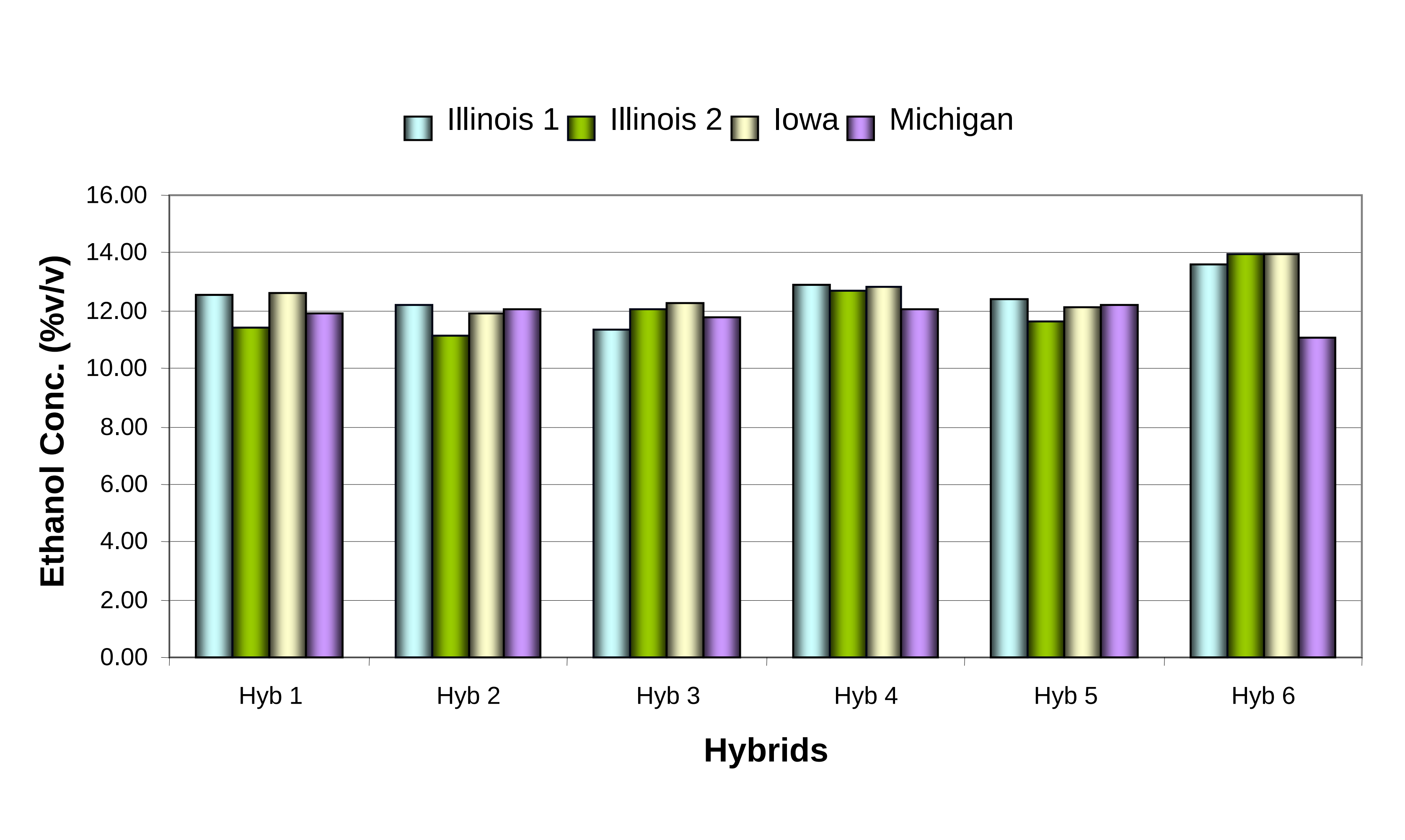
Starch Yield and Ethanol Conc. (Zhan et al, 2005)



Zhan, X., Wang, D, Tuinstra, M.R., Bean, S., Sieb, P.A. and Sun, X.S. 2003. Ethanol and lactic acid production as affected by sorghum genotype and location. Industrial Crops and Products 18:245-255

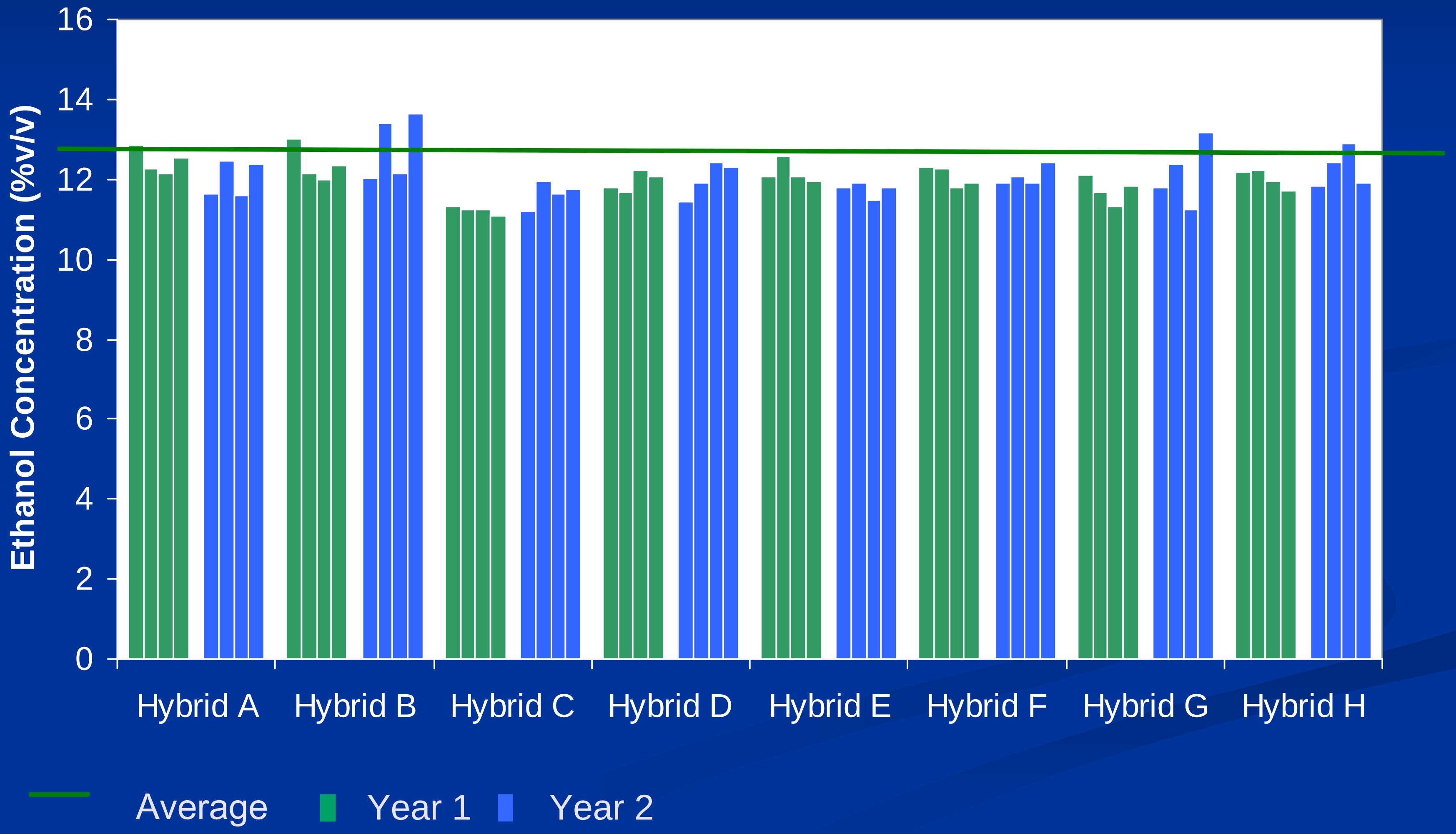
Variability Due to Environment

Effect of Planting Location

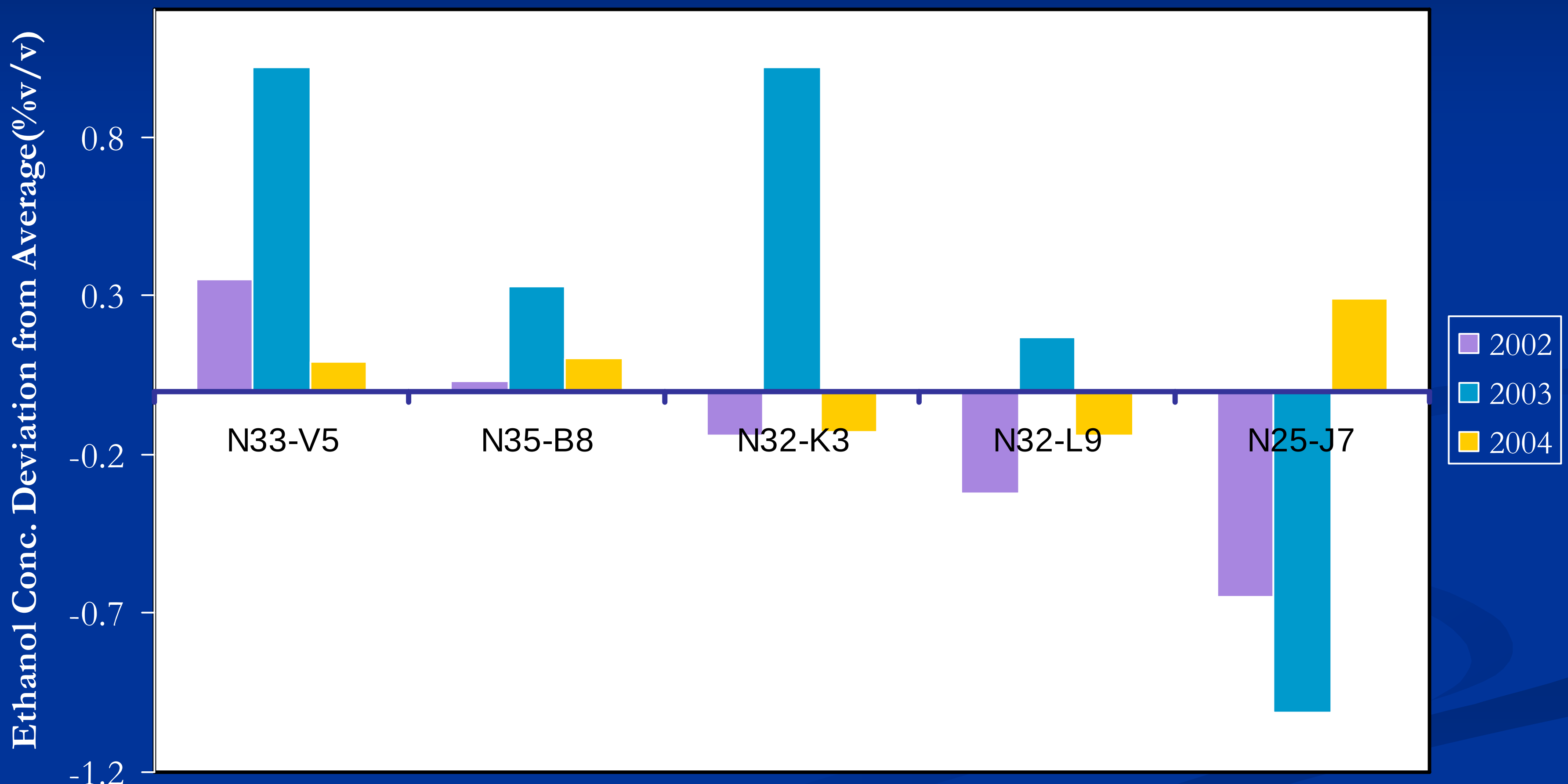


Singh, V. and Graeber, J.V. 2005. Effect of corn hybrid variability and planting location on ethanol yields. Trans. ASAE 48:709-714

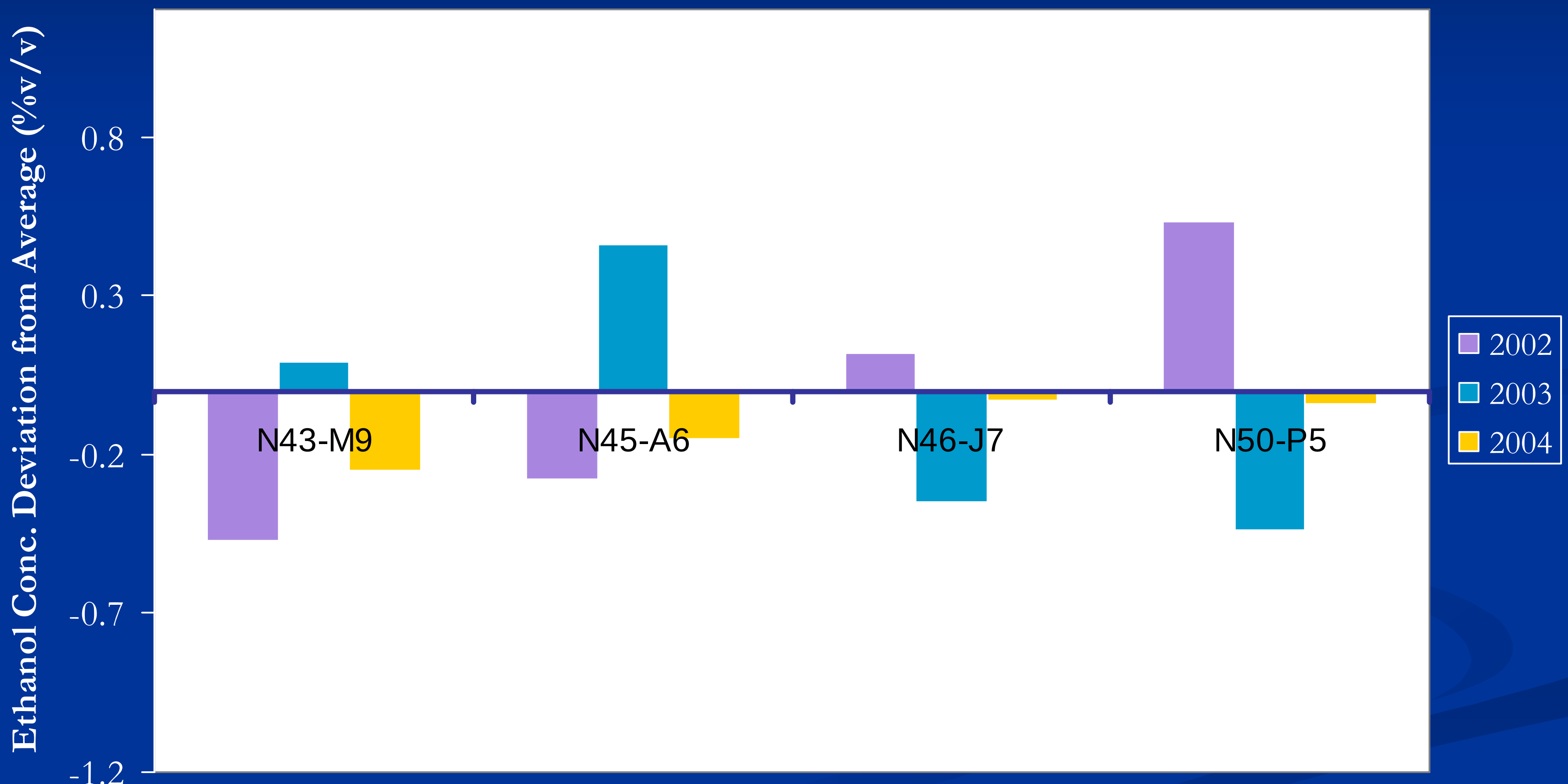
Significant Interaction between Hybrids and Years



Comparison of Ethanol Conc. for 5 Hybrids Over 3 Years

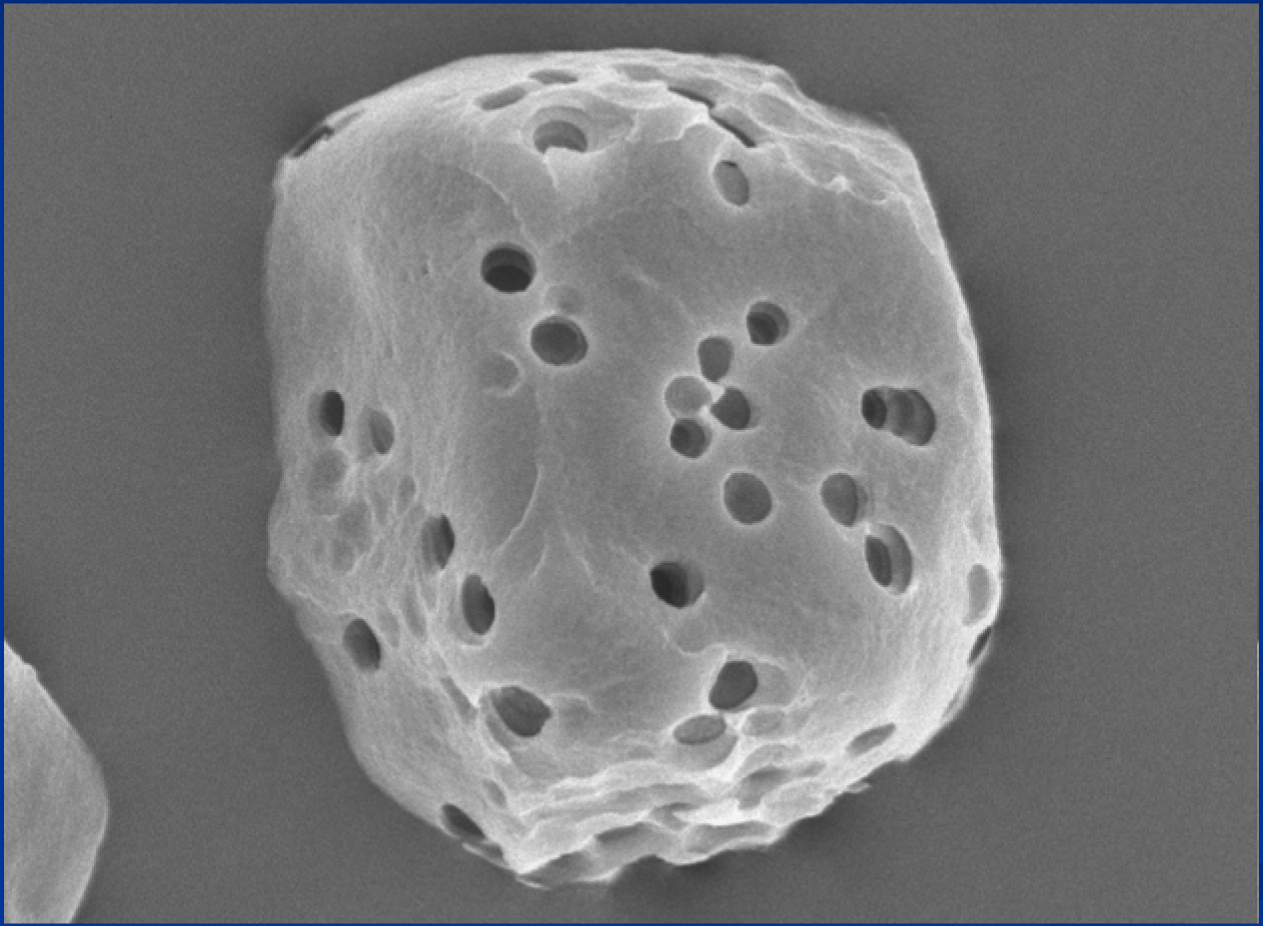


Comparison of Ethanol Conc. for 4 Hybrids Over 3 Years

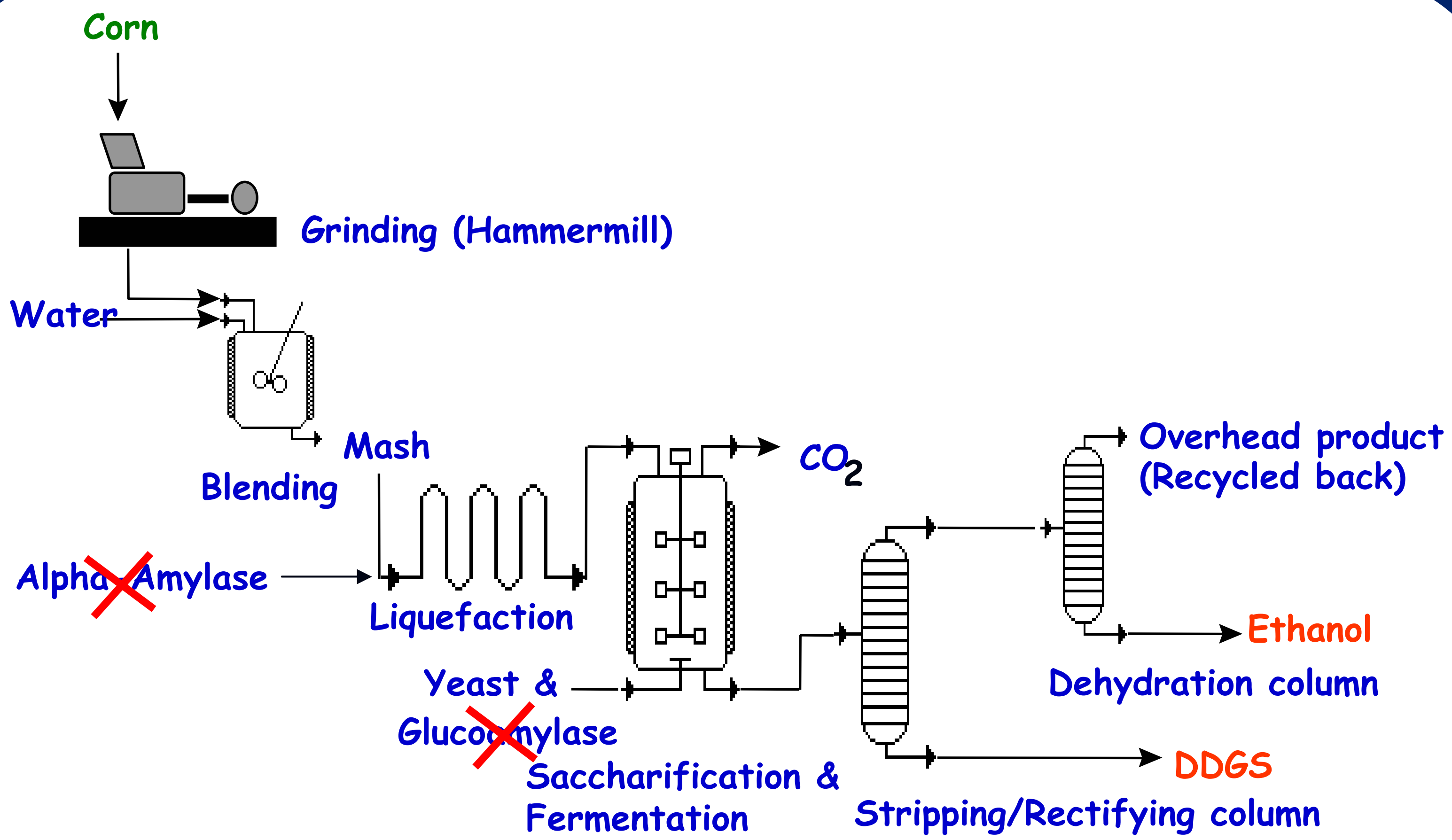


Granular Starch Hydrolyzing (GSH) Enzymes

Starch Granule Hydrolyzed by GSH Enzyme

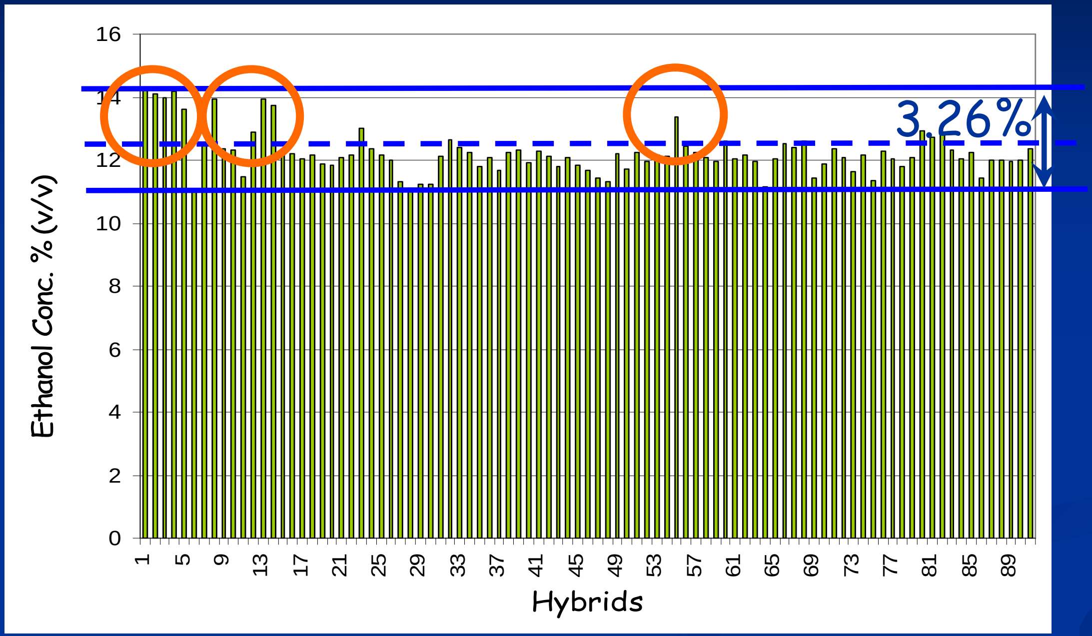


Dry Grind Process



Wang, P., Singh, V., Johnston, D.B., Rausch, K.D. and Tumbleson, M.E. 2006. A granular starch hydrolyzing enzyme for the dry grind corn process. Cereal Chem. (In review)

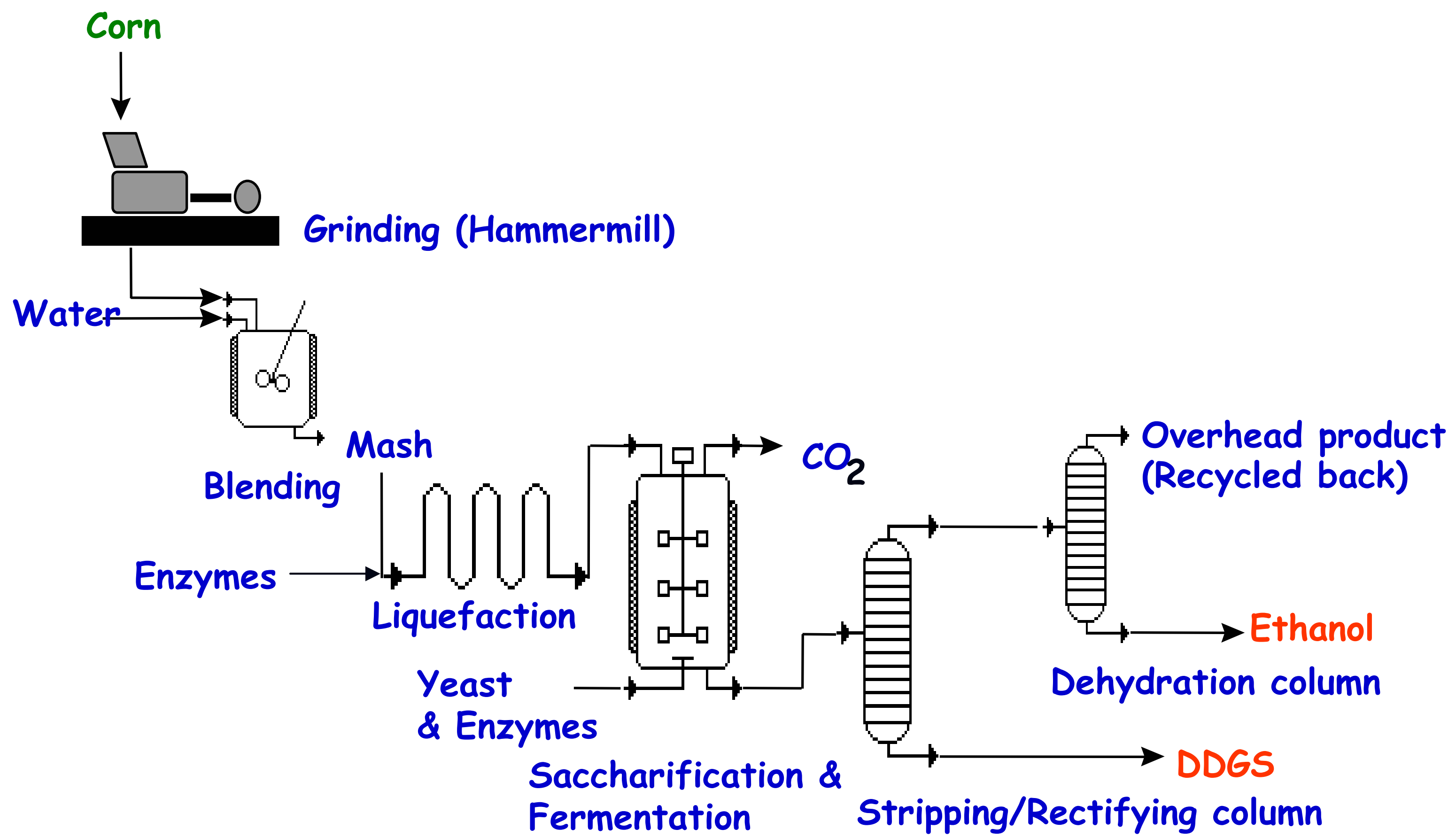
Extent of Hybrid Variability for Ethanol Production



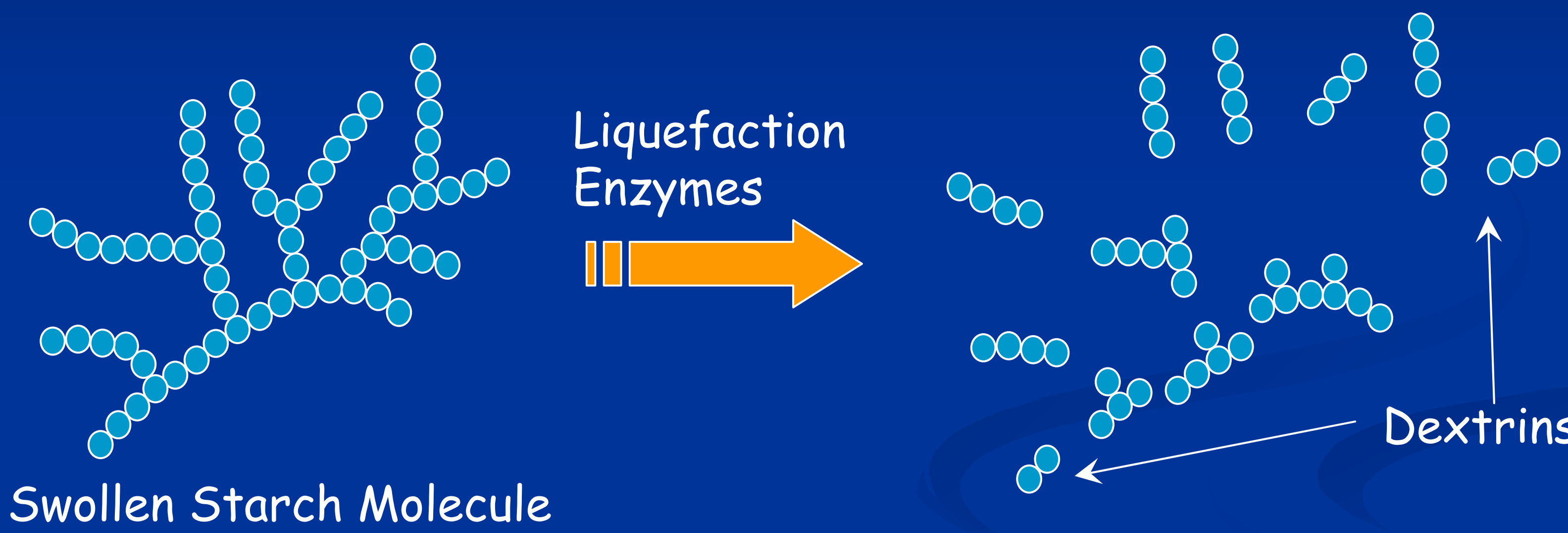
With GSH enzyme hybrid variability was only approximately 11% compared to 23% with conventional dry grind enzymes

Development of New Transgenic Corn Specifically for Dry Grind Process

Dry-grind Process



Liquefaction Enzymes for Dry Grind Ethanol Process

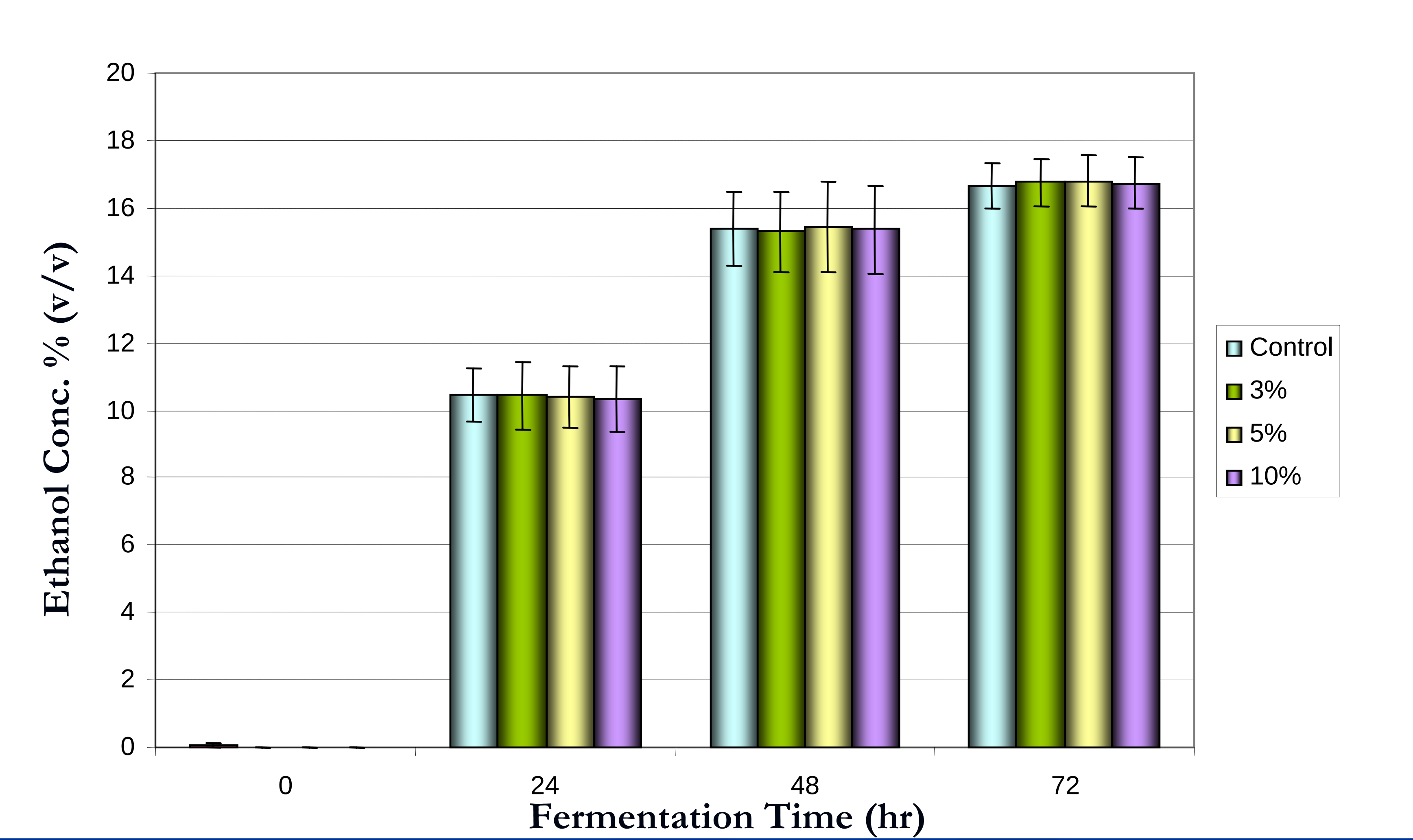


- A new transgenic corn with endogenous liquefaction enzymes has been developed that is activated
  - in presence of water at high temperature

Amylase Expressing Corn

500 ml Fermentations

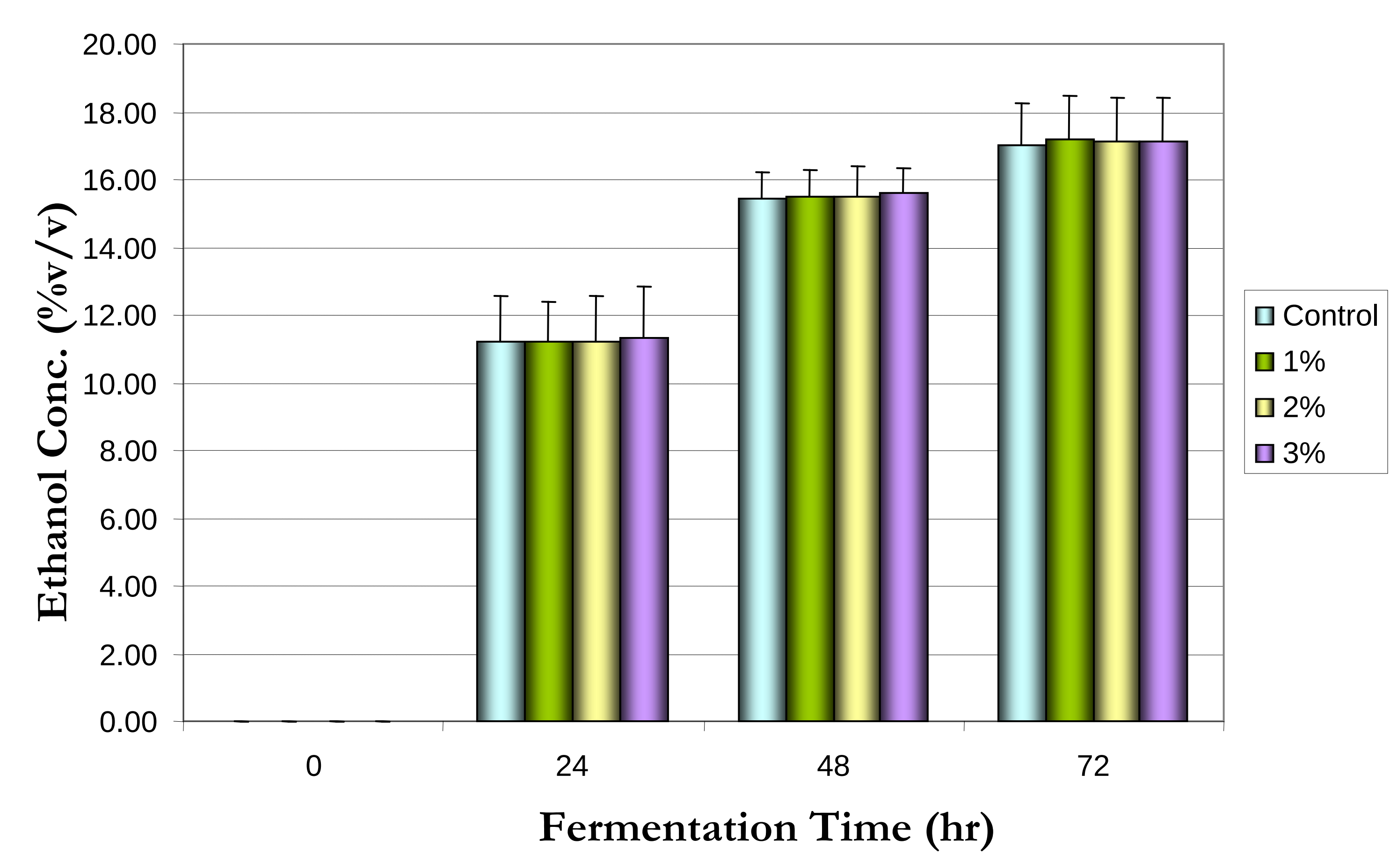
Control vs 3, 5 and 10% amylase corn addition



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. (In press)

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. (In press)

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, Batie, C.J., Aux, G.W., Rausch, K.D. and Miller, C. 2006. Dry grind processing of corn with endogenous liquefaction enzymes. Cereal Chem. (In press)

Dry Milling (1 kg Procedure)

Fractions	Control	0.1% Amy	1.0% Amy	10% Amy
+5(Large Grits)	31.42	33.23	30.59	28.73
-10+24 (Small Grits)	29.88	28.91	31.79	31.46
-24(Fines)	18.01	17.47	16.65	18.18
Germ	13.02	12.88	13.32	13.79
Pericarp	7.45	7.57	7.64	7.60
Total	99.78	100.06	99.98	99.76

Singh, V, Batie, C.J., Rausch, K.D. and Miller, C. 2006. Wet and dry milling properties of dent corn with addition of amylase corn. Cereal Chem. (In press)

Wet Milling (1 kg Procedure)

Fractions	Control	0.1% Amy	1.0% Amy	10% Amy
Solubles (%)	4.52	4.40	4.38	4.82
Germ (%)	6.21	6.35	6.43	6.74
Fiber (%)	12.36	11.72	11.98	11.90
Starch (%)	67.24	67.66	67.33	66.19
Gluten (%)	10.25	10.18	10.16	10.65
Total (%)	100.59	100.31	100.29	100.30

Singh, V, Batie, C.J., Rausch, K.D. and Miller, C. 2006. Wet and dry milling properties of dent corn with addition of amylase corn. Cereal Chem. (In press)

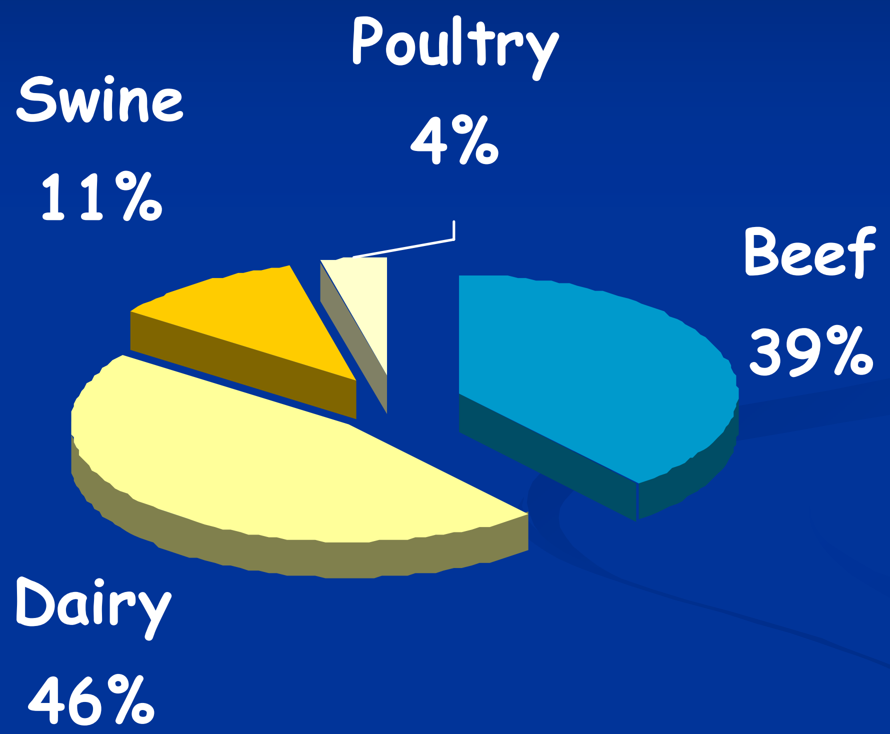
Corn for Modified Dry Grind Processes

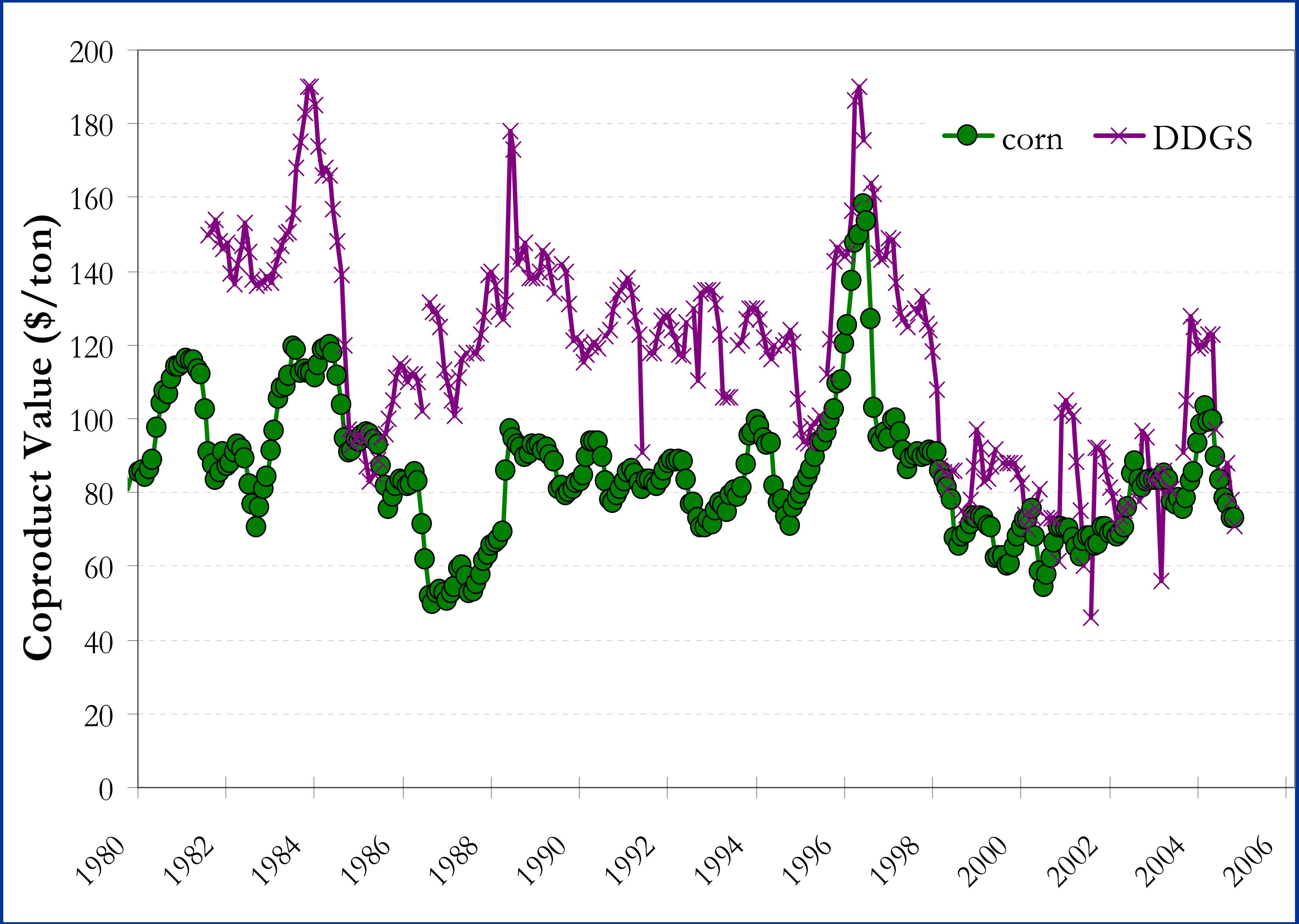
Modified Dry Grind Ethanol Processes

- Wet fractionation technology: similar to wet milling
  - Enzymatic dry grind process (E-Mill process)
  - Recovers germ, pericarp fiber and endosperm fiber at front end of dry grind ethanol plant
- Dry fractionation technology: similar to dry milling
  - Dry degerm defiber process (3D process)
  - Recovers germ and pericarp fiber at front end of dry grind ethanol plant

These modified dry grind processes, recover valuable coproducts, improve efficiency of dry grind process and reduce volume of DDGS produced

DDGS Utilization (2005)



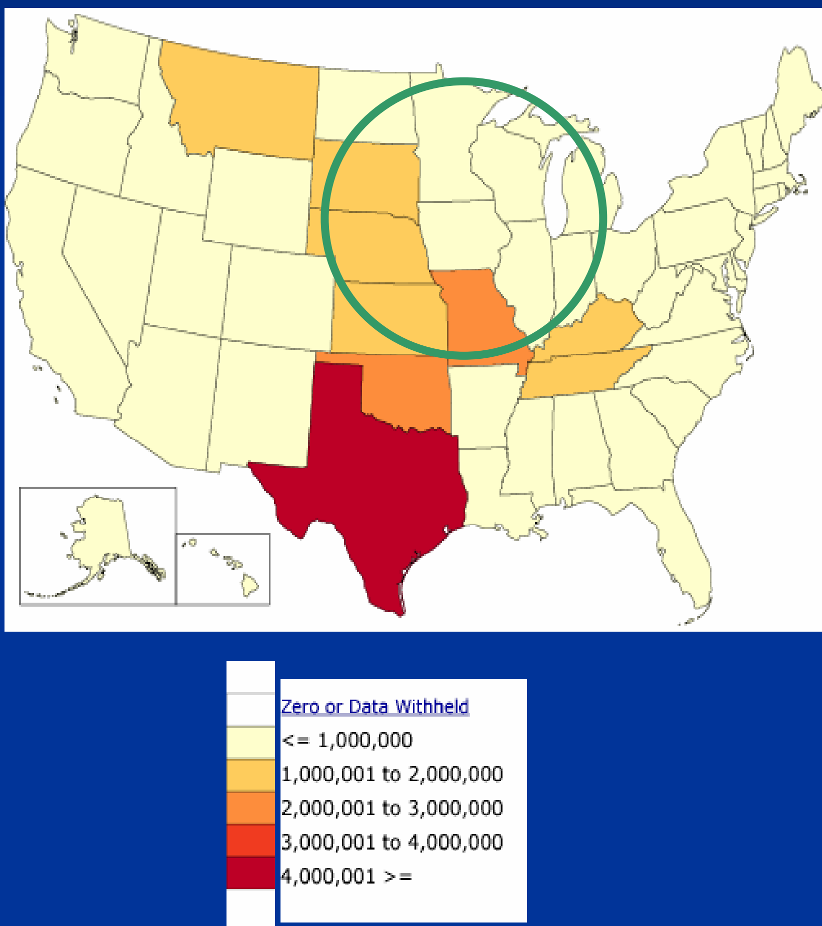


Economic Research Service 2005: www.ers.usda.gov/db/feedgrains/

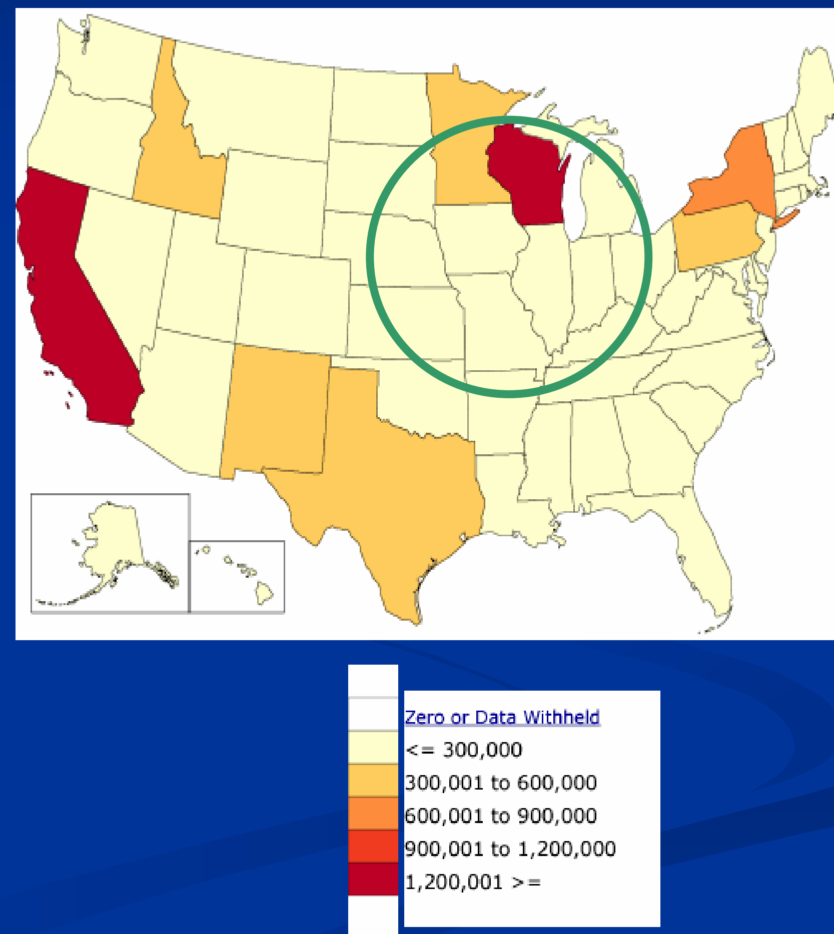
Cattle and Calves Inventory

Source: USDA-NASS 2002 Census of Agriculture

Beef Cows



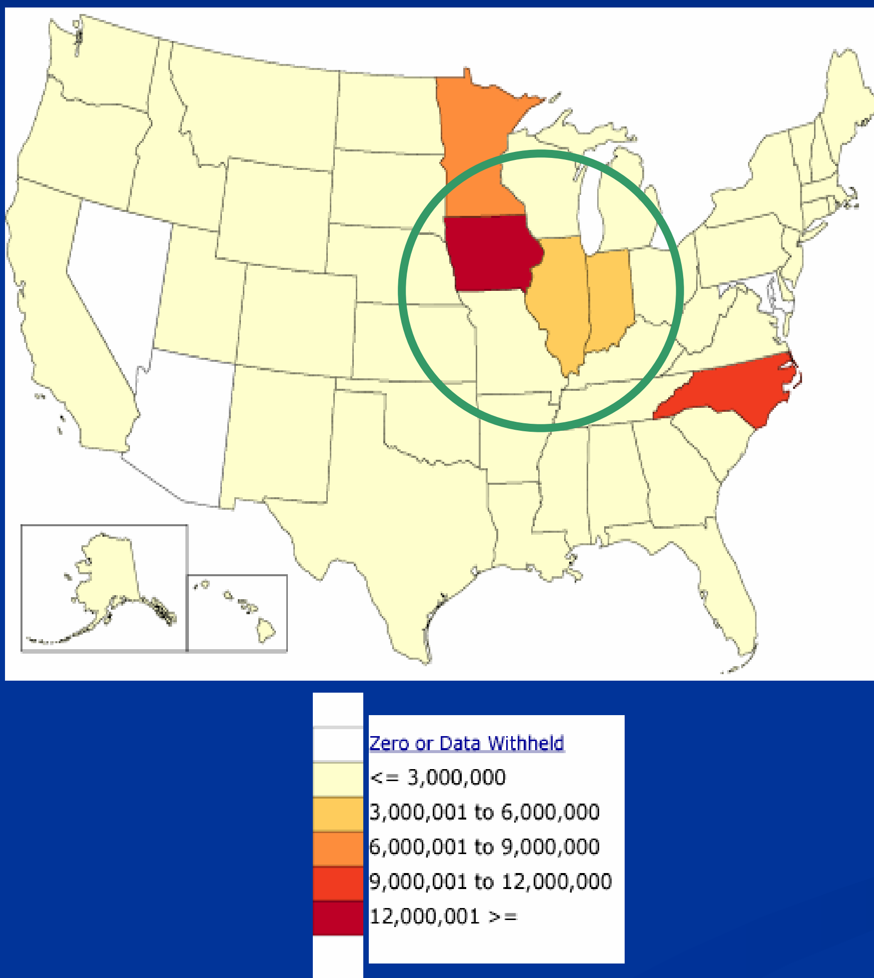
Milk Cows



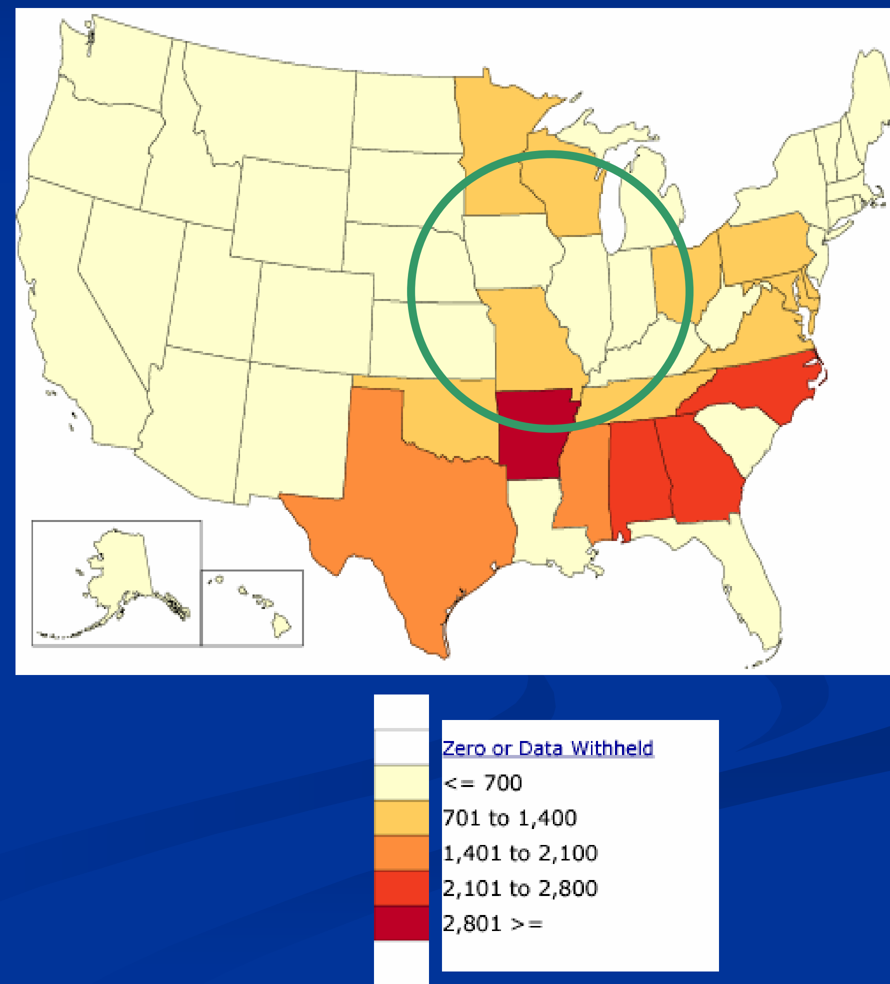
Poultry and Swine Inventory

Source: USDA-NASS 2002 Census of Agriculture

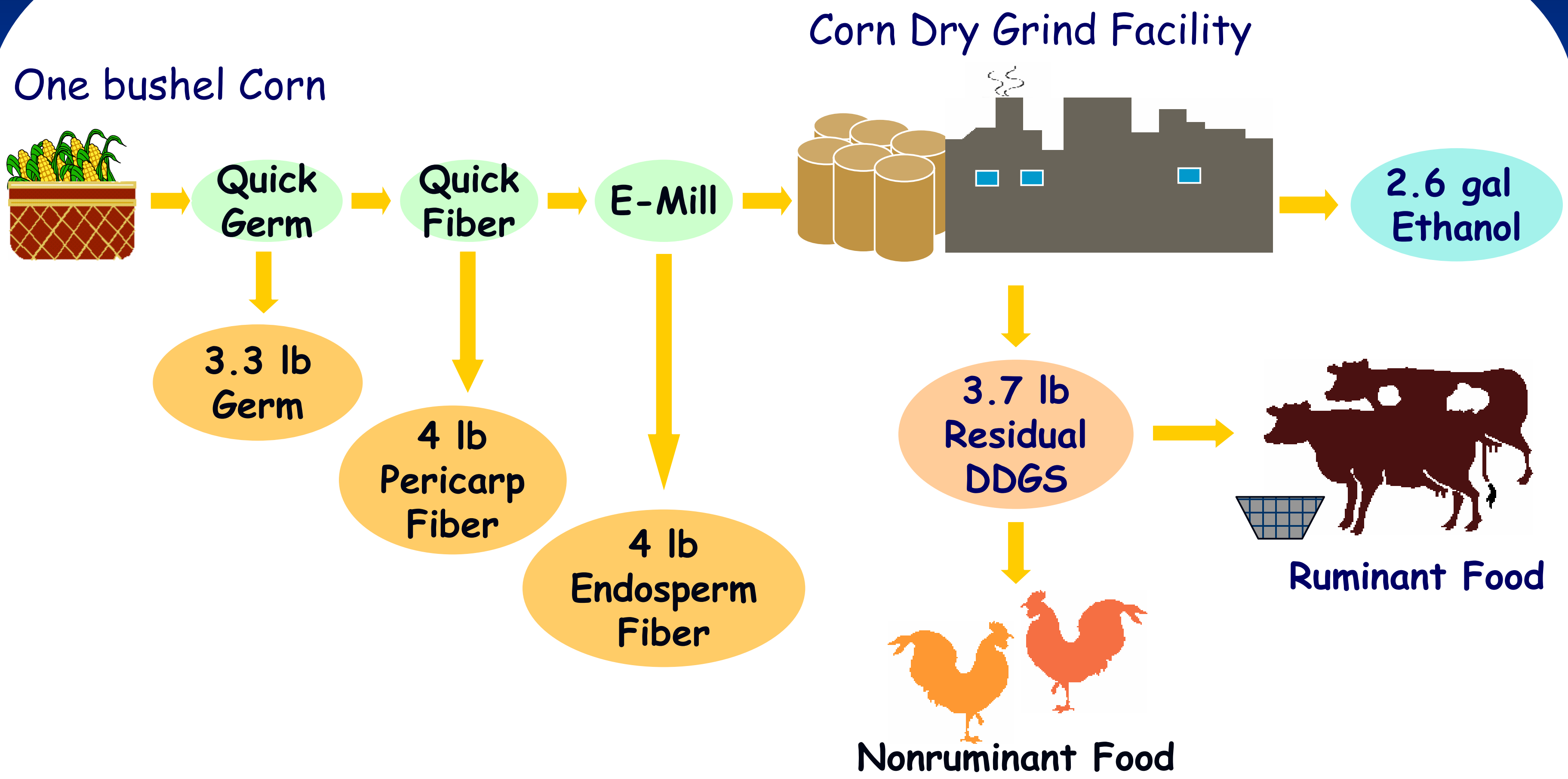
Pigs



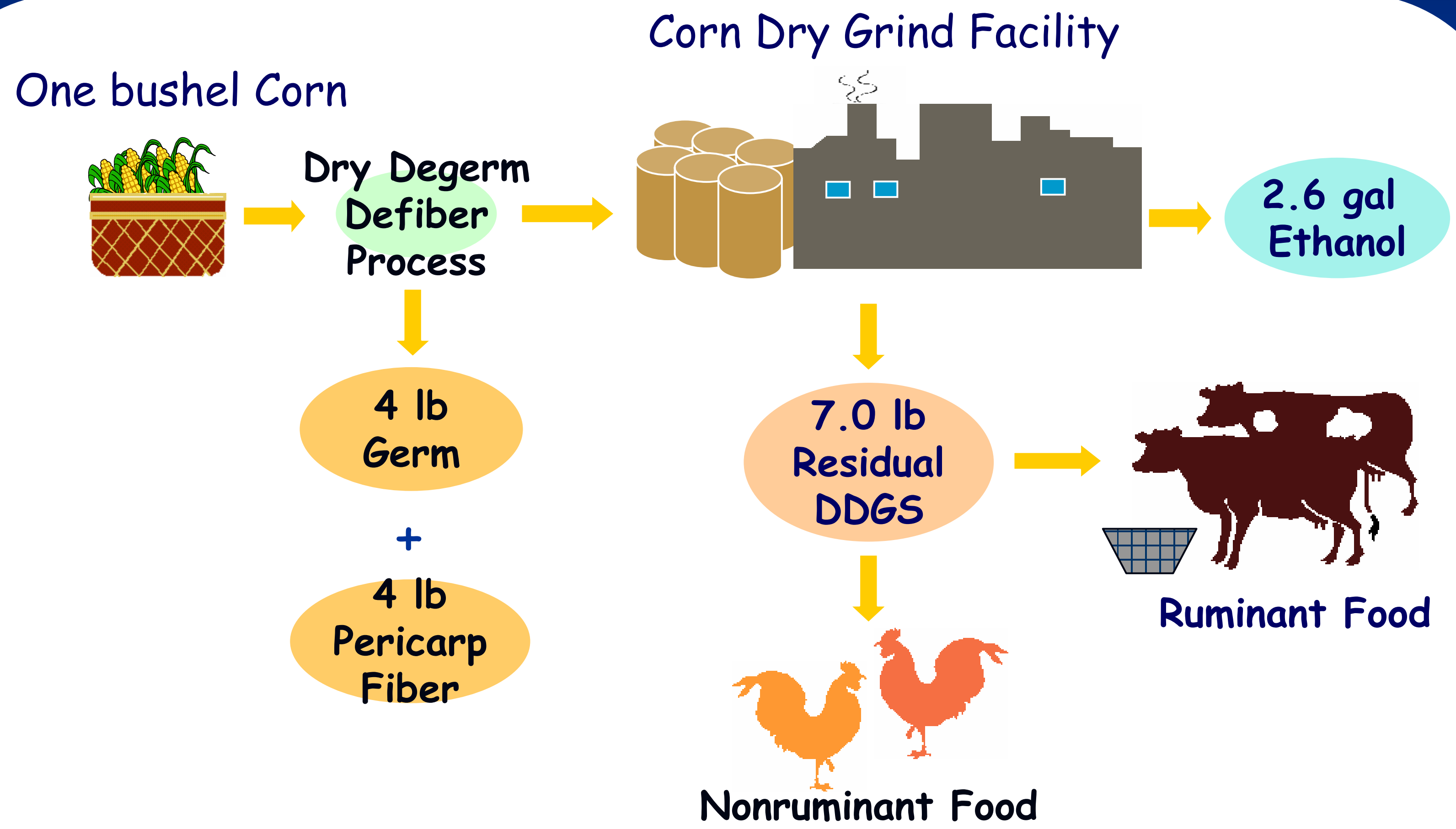
Broiler and Other Meat Type Chicken



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



Dry Fractionation Technology:
Dry Degerm Defiber Process (3D Process)



Effect of Hybrid Variability on Enzymatic Dry Grind Corn Process

<u>5 Hybrids</u>
N36-R6
N22-T8
NX2603
N34-F1

x

<u>2 Locations</u>
Waupun, WI
Brookings, SD

→ Enzymatic Dry Grind Process → Coproducts and Ethanol Yield

Coproducts and Ethanol Yield for Waupun, WI

Fraction (% db)	N36-R6	N22-T8	NX2603	N34-F1
Germ	9.18	9.22	9.41	8.85
Pericarp Fiber	8.62	7.79	8.61	6.04
Endosperm Fiber	3.89	5.46	5.04	3.93
DDGS	7.38	8.14	8.29	8.31
Ethanol Conc. (% v/v)	13.41	14.60	14.34	13.35

Coproducts and Ethanol Yield for Brooking, SD

Fraction (% db)	N36-R6	N22-T8	NX2603	N34-F1
Germ	8.87	9.21	9.54	8.89
Pericarp Fiber	10.45	7.51	9.37	8.05
Endosperm Fiber	5.60	6.50	5.53	6.56
DDGS	8.01	10.83	9.34	8.63
Ethanol Conc. (% v/v)	13.40	12.93	13.56	13.38

Conclusions

- New Developments in Dry Grind Corn Processing
  - Significant variability in corn hybrids for dry grind ethanol production
    - 23% total variability
    - 75% of this variability is due to genetics and 25% is due to environment
    - Variability can be reduced with hybrid specific processing or by using GSH enzyme
  - Negligible or weak correlation between starch content or extractability and starch fermentability
  - Corn with endogenous liquefaction enzymes
  - Hybrid specific processing for conventional and modified dry grind processes to increase ethanol yield and coproduct quality