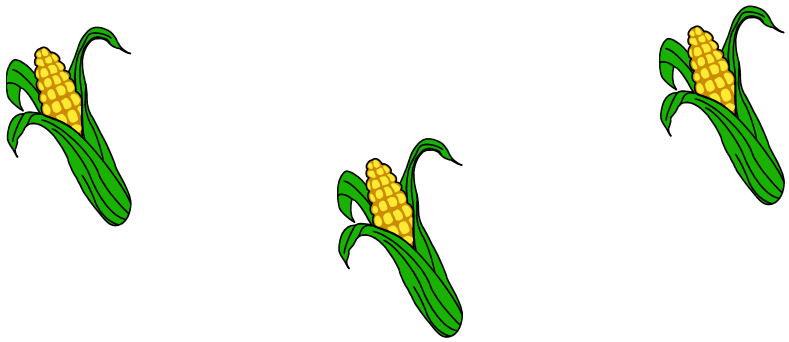
PROCEEDINGS:

CORN CONGRESS AT MINER INSTITUTE



February 4, 2016

Corn Congress at Miner Institute

Thursday, February 4, 2016

BERC Auditorium, 586 Ridge Road, Chazy, NY

10:00 AM	**Dr. Eric Young**, Miner Institute, "Evaluating Yield and Quality of BMR and non-BMR Corn Hybrids."
10:45 AM	**Dr. Margaret Smith**, Cornell University, "GMOs, Stacks, Traited Hybrids, Frankenfoods — What Does it All Mean?"
12:00 PM	**Hot Lunch** available for $5.00
12:45 PM	**Anita Deming**, CCE Essex County, "Crop Insurance – newest options."
1:00 PM	**Dr. Francis Glenn**, President, Glenn Seed, Ltd., "Breeding for corn silage yield and economics."
2:15 PM	**Dr. Rick Grant**, Miner Institute, "Making Milk with Corn Silage."

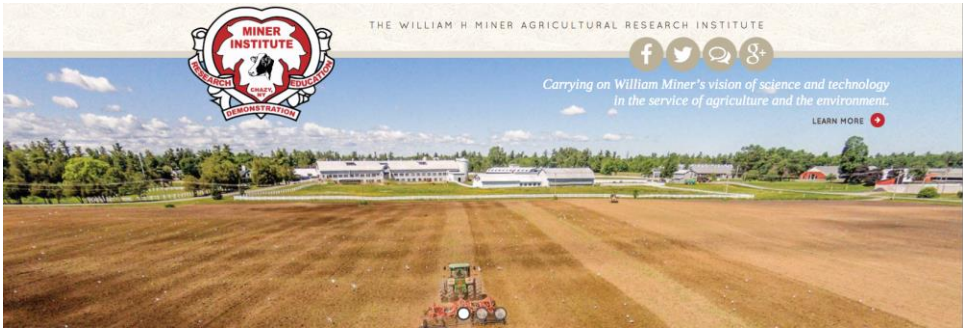
Free Admission!

Corn Congress is organized in collaboration with Cornell Cooperative Extension.
1.25 NY /1 Vermont Pesticide applicator credits will be available. Pre-registration is encouraged. For more information contact: Wanda Emerich, 518-846-7121 x117 or Emerich@whminer.com

Miner Institute is located in Chazy, NY on Miner Farm Road, Route 191- 1 mile west of Interstate 87, exit 41. Travel time is approximately 1 hour south of Montreal, 20 minutes north of Plattsburgh, NY, 1.5 hours from Burlington, VT, or 3 hours north of Albany, NY.

Evaluating Yield and Quality of BMR and Non-BMR Corn Hybrids

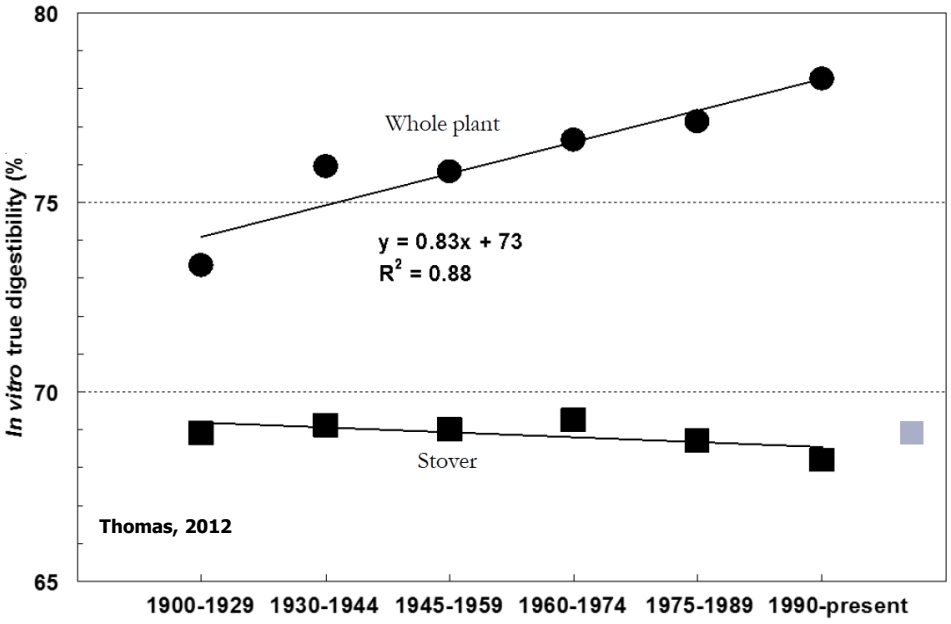
Eric Young, Miner Institute
2016 Corn Congress at Miner Institute
Chazy, NY
February 4, 2016



Corn Hybrid Selection

- **Silage <7% of US corn market**

Thomas, 2012



Relationship between corn forage *in vitro* true digestibility and era of release for whole-plant and stover.

Corn Silage Fundamentals

- **Good drainage is essential**
- **Plant early but not too early**
- **pH ≥ 6.2**
- **Hybrid traits, maturity**
- **Ample nitrogen**
- **Maintain soil quality**

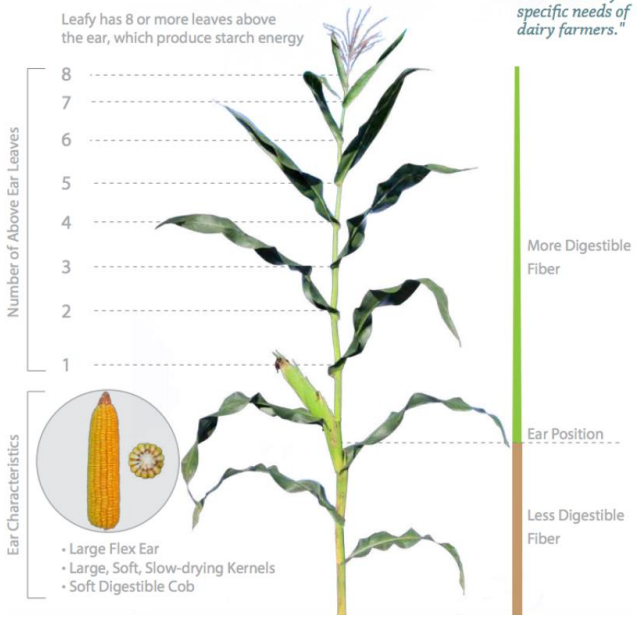
Weather Rules

- **Weather is largest factor influencing annual crop yield variation in US**
- **Weather also affects corn quality:**
  - **Starch and fiber digestibility**
- **Importance of *growing environment***
  - **Weather-soil-management interactions on yield & quality**

Corn Hybrid Selection: Navigating the Maize

- **Dual purpose hybrids:**
  - Bred for grain but harvested for silage
  - Some sold as "silage hybrids"
- **Leafy hybrids:**
  - Bread for silage
  - More leaves above the ear; good harvest window and fiber digestibility
- **Brown Midrib:**
  - **Silage-specific only**
  - Genetic mutation conferring lower lignin

Leafy Hybrids



"My selection criteria for silage hybrids were determined by specific needs of dairy farmers."

Dr. Francis B. Glenn, Glenn Seed Ltd. Inventor of the Leafy hybrid

Brown Midrib (BMR)

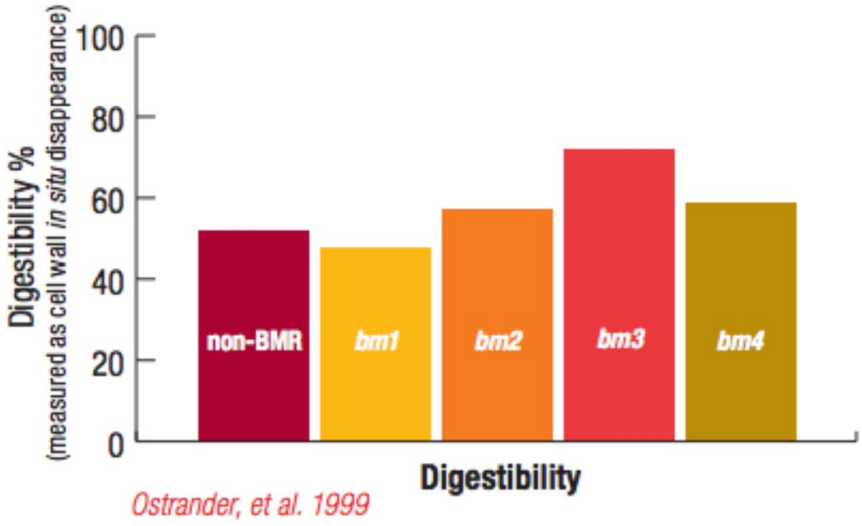
- **Enhanced whole-plant fiber digestibility**
- **Lower yielding, less tolerant of stress**
- **Yields/agronomics markedly improved since release in the late 1990's**

From Graves & Erickson, 2010

BMR corn hybrids: bm-1 and bm-3

- Natural corn mutation- not a "gmo"
  - Bm1 and bm3 genotypes used
- BMR contains less lignin and higher fiber digestibility than non-BMR corn (Oba and Allen, 1999)
  - bm3 corn had 34% less lignin and invitro NDFD of 19% higher than non-bm3 (Eastridge, 1999)

Figure 1: Digestibility of normal and BMR mutants of corn silage



Ostrander, et al. 1999

What is an average hybrid? (1995-2008)

Lauer et al., 2009

Trait	N	Forage yield	NDF	NDFD	Starch	Milk per Ton	Milk per Acre
		T/A	%	%	%	Lbs/T	Lbs/A
Bmr	56	6.2	48.3	68.4	26.3	3380	21300
CB	343	7.9	46.5	60.2	30.5	3260	25600
CB, LL	142	7.9	46.6	60.2	30.5	3250	25700
CB, RR	161	7.8	46.1	60.0	31.4	3270	25600
CB,CR,RR	171	7.8	46.1	59.9	31.2	3270	25400
Leafy	96	7.8	48.2	59.3	27.5	3190	24900
RR	125	7.6	47.0	59.4	30.2	3220	24500
Normal	1304	7.6	47.1	60.0	29.7	3230	24500
LSD(0.05)		0.8	2.7	1.8	3.9	110	2500
Average hybrid	2665	8.0	46.7	59.8	30.6	3240	26000

BMR vs. non-BMR: Milk Trials

- Effect of Corn Silage Hybrid on Dry Matter Yield…and Milk Production by Dairy Cows (Ballard et al., 2001)
- 75 midlactation Holstein blocked and assigned randomly to one of three rations with 31% corn silage (DM basis)
- **BMR had a lower yield but resulted in more milk production than the a dual purpose or leafy hybrid**

BMR vs. non-BMR

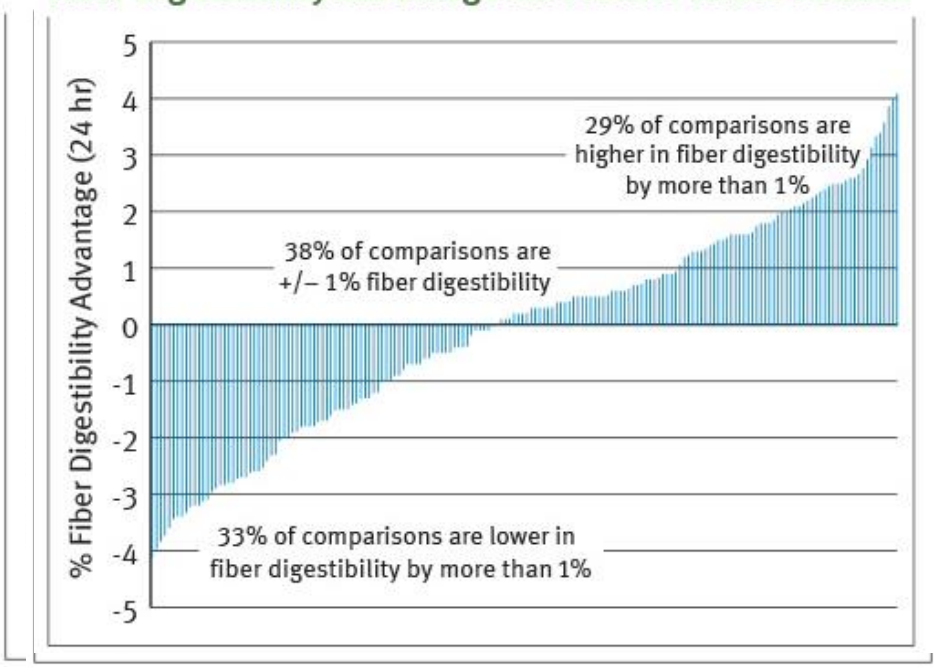
Gencoglu et al., 2008

- **Results from 11, bm-3 - vs. non-BMR in feeding trials with lactating dairy cows were analyzed from JDS publications (since '99)**
- **ivNDFD (% of NDF) of the bm3 corn silages was 11.5%-units greater on average than non-BMR corn**

BMR vs. non-BMR

- **Dry matter intake was 1.2 kg/d greater (*P* < 0.01) for cows fed bm3 corn silage**
- **Milk yield was 1.7 kg/d greater (*P* < 0.0001) for cows fed bm3 corn silage**
- **Farm-specific economics, corn silage inventory, and management affect the fit of BMR on a given dairy**

Fiber Digestibility Advantage for Pioneer BMR Products



bm3 vs. bm1

Only Mycogen Seeds offers combined superior BMR genetics and traits in one package

	Mycogen® brand BMR	Competitive BMR brands
BMR gene mutation	All hybrids contain the superior *bm3*. Highest digestibility of all BMR gene mutations.[1]	Unknown gene mutation(s).
Milk production results	Proven in 16 lactation trials published since 1999. Average of 2.2 more kgs of milk per cow per day.	No published lactation trials.
Genes and trait options	9 hybrids available commercially with leading trait technologies, including SmartStax™.	Limited hybrid and trait choices.
Maturity options	Range of relative maturity from 2700 to 3200 chu.	Limited relative maturity ranges.

REFERENCES:

Barnes RF, Muller LD, Bauman LF, Colenbrander VF. *In Vitro* Dry Matter Disappearance of Brown Midrib Mutants of Maize (Zea Mays L.). *J Anim Sci.* 1971; 33:881-884.
Lechtenberg VL, Muller L D, Bauman LF, Ryhkerd CL, Barnes RF. Laboratory and *in vitro* evaluation of inbred and F2 populations of brown midrib mutants of Zea mays L. *Agronomy Journal* 1972; 64:657-660.
Marita JM, Vermerris W, Ralph J, Hatfield RD. Variations in the cell wall compostion of maize brown midrib mutants. *J Agric Food Chem.* 2003; 51:1313-1321.
Oba M. and M. S. Allen. 1999. Effects of brown midrib 3 mutation in corn silage on dry matter intake and productivity of high yielding dairy cows. *J. Dairy Sci.* 82:135–142.
[1]Ostrander B, Maillot M, Toillon S, Barriere Y, Pollacsek M, Besle J. Cell wall phenolics and digestibility of normal and brown midrib maizes in different stem sections and across maturity stages. *J Sc. Food Agric.* 1999; 79:414-415.

http://www.dowseeds.com/en-ca/canada/agronomy/silage-corn/bmr_silage_corn

Mycogen® SEEDS

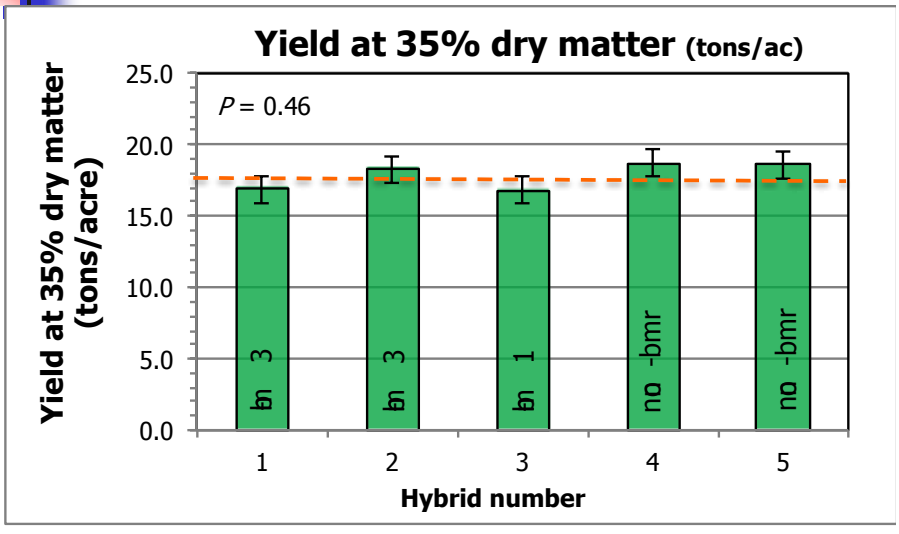
2015 Corn Silage Yield/Quality Trial at Miner Institute

- Farmer-driven research in NNY:
  - How do bm-1 and bm-3 hybrids compare?
- Dow AgroSciences/Mycogen Seeds: bm-3 gene
- Dupont/Pioneer: bm-1 gene

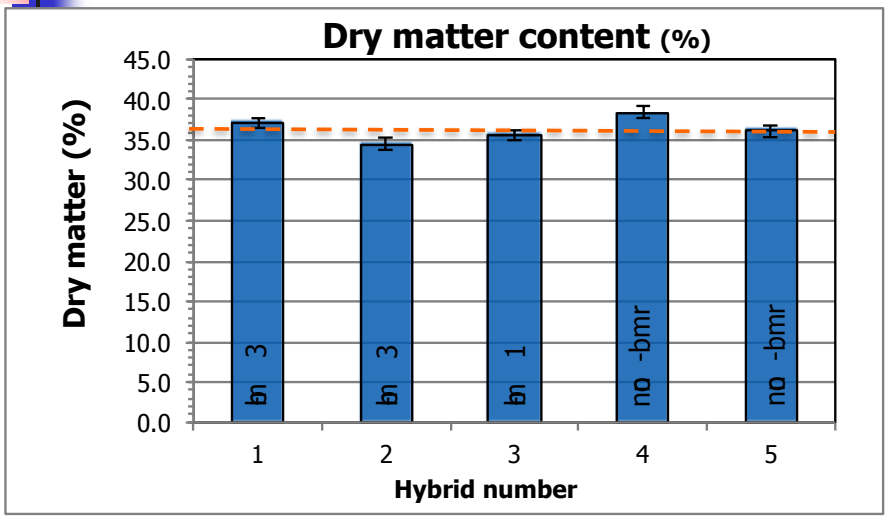
Study Hybrids and Experimental Design

- Five hybrids: Two bm-3 hybrids, one bm-1, and 2 non-BMR hybrids.
- 95-day relative maturity to 107 day
- Planted 5/21 harvested on 10/2
- Planted at ~34,000 seeds/acre
- Four replicates in a randomized complete block design (6 rows x >500 ft)

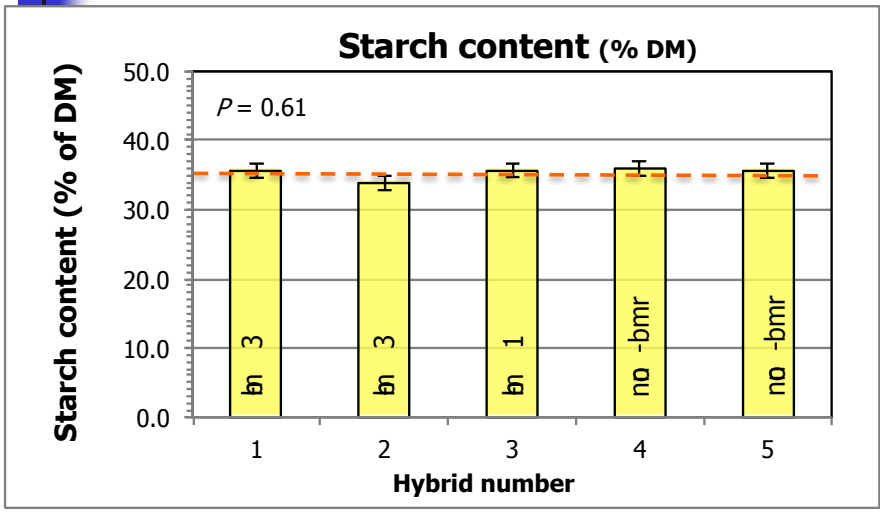
Results: Yield



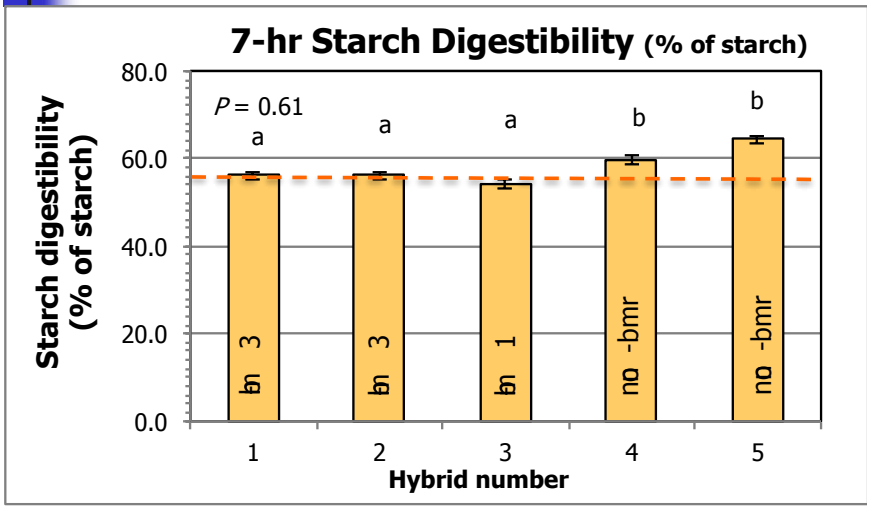
Harvest Moisture



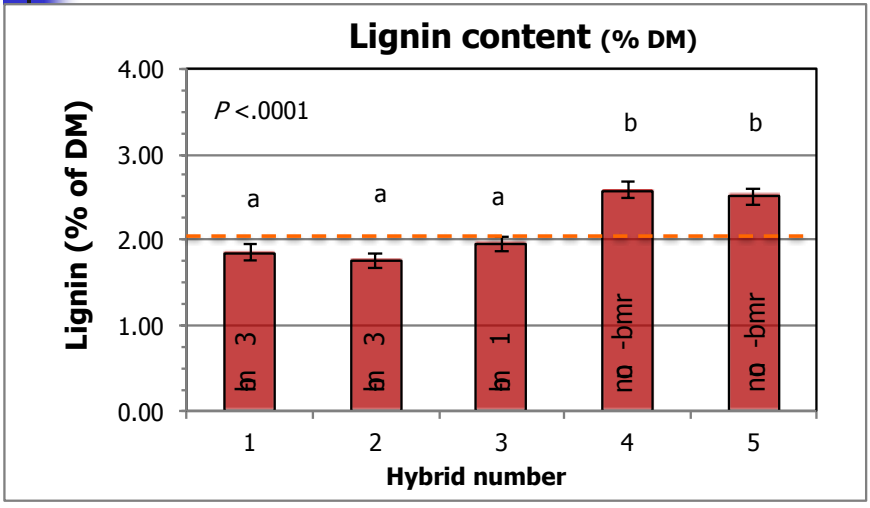
Starch Content



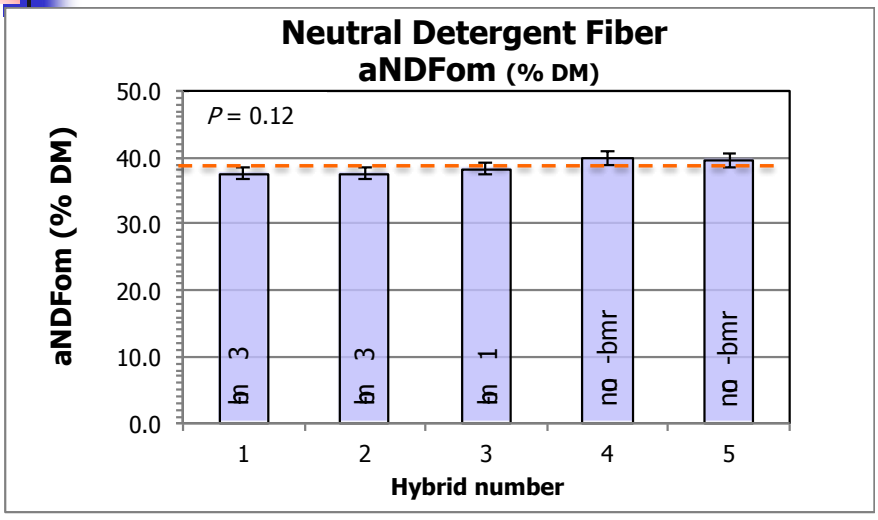
7-hr Starch Digestibility



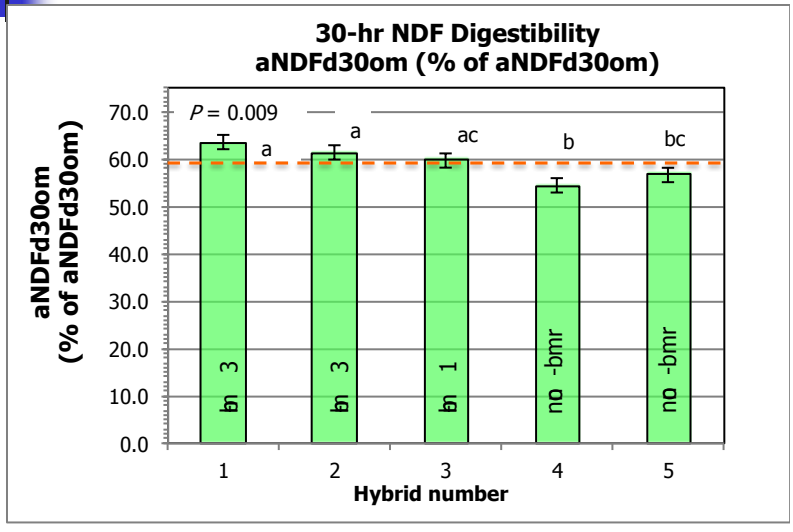
Lignin Content



Neutral Detergent Fiber



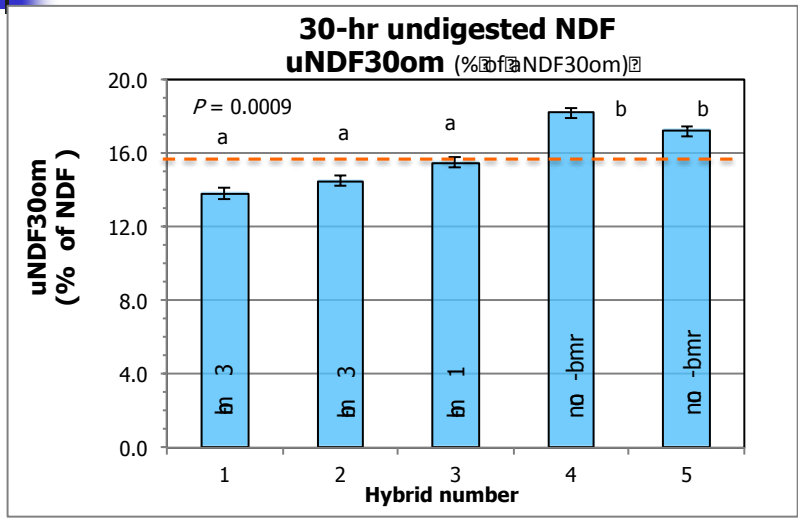
30-hr NDF Digestibility



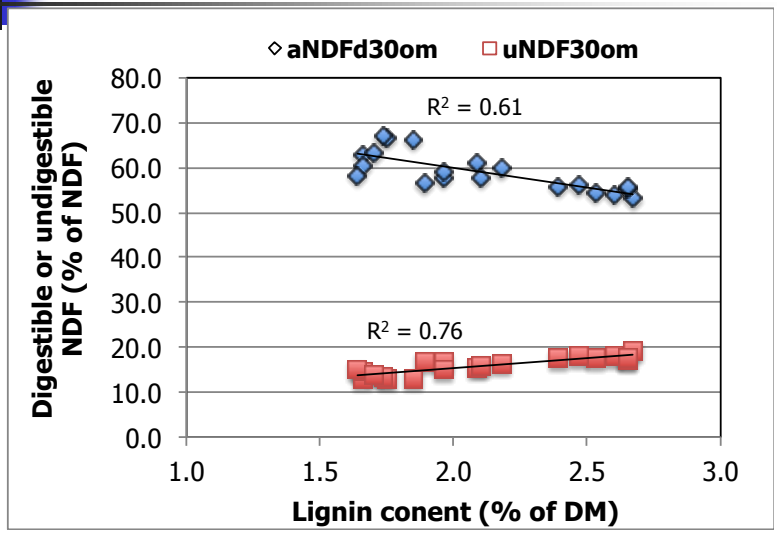
NDF Digestibility and Milk Yield Potential

- For every 1% increase in NDFd there was an increase of 0.55 lb/cow/day (Oba and Allen, 1999)
- >40% corn silage rations, 1% NDFd increase resulted in a 0.31 lb/cow/day milk production increase (Jung et al., 2010)
- Depends on production level and lactation stage; greater response with higher producing animals (Grant, 2012)

30-hr Undigested NDF



30-hr uNDF and Lignin



BMR Study: Conclusions

- No differences in yield, starch, or NDF
- BMR is more digestible, less uNDF
- bm-1 and bm-3 results similar
- BMR is more expensive but increased milk production could offset cost?
- BMR is designed for your best fields
- BMR is not for all farms or all acres

Indigestible vs Undigested NDF (Mertens, 2013)

- iNDF: theoretical and defined by model; indigestibility measured at infinite time.
- uNDF: Undigested NDF is what we measure at a defined time point in the lab
  - uNDF 30, 120 and 240h for pools: CNCPS
  - uNDF240 analytical estimate of iNDF

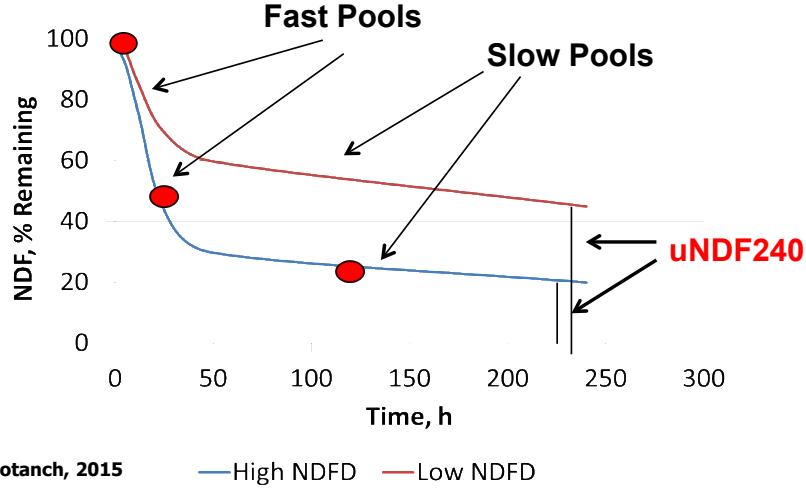
From Cotanch, 2016

Undigested NDF: uNDF What is it?

Cotanch, 2016

- Not new concept:
- Opposite of digestible NDF (dNDF)
  - 100 – uNDF = dNDF as % of NDF (not DM)
  - 100% -uNDF% = NDFD%
- Undigested NDF residue after a specified time of digestion
  - 0, 24, 30, 48, 120, 240 h
  - At time 0h = 100% uNDF or NDF

What's Undigested NDF?



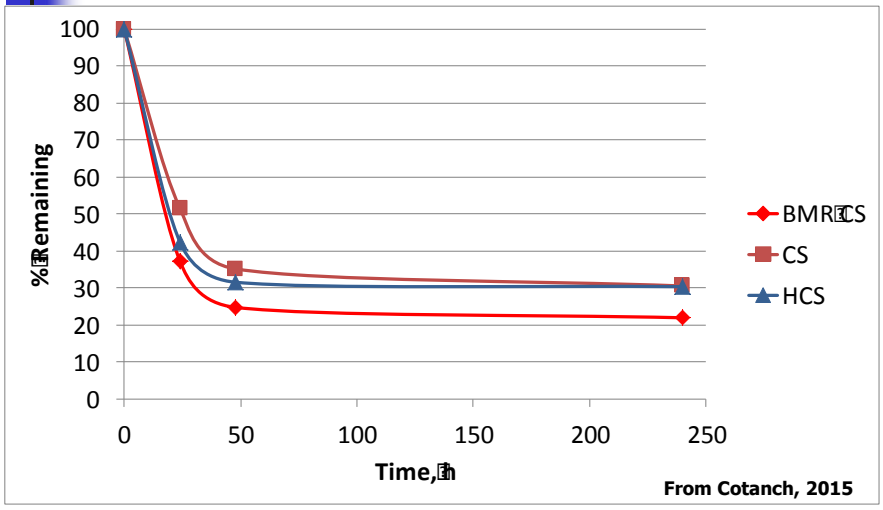
From Cotanch, 2015

uNDF: How is it measured?

- **Lab: in vitro**
  - **Tilley-Terry: individual flask fermentation**
    - **Gold Standard method: 1.5um filter**
  - Ankom Daisy: batch fermentation
    - Caution: Much different values than Tilley-Terry method: 25.0um filter
- Lab: NIR-based: Need to calibrate with wet chemistry values
- Cow: in situ
  - Dacron bags in rumen

From Cotanch, 2015

BMR and non-BMR uNDF



From Cotanch, 2015

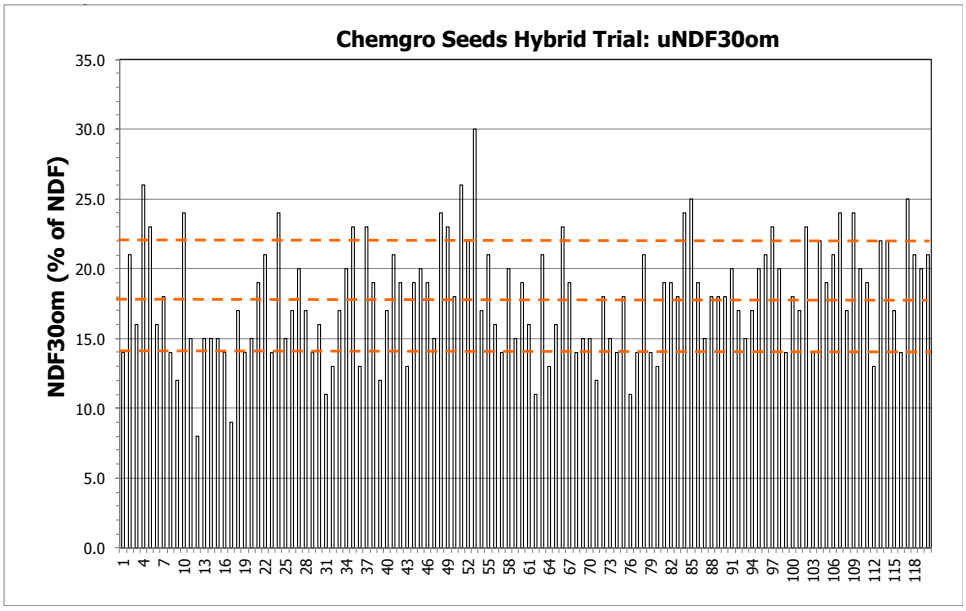
Measured ranges in uNDF240

(source: Dairy One, May, 2015 newsletter)

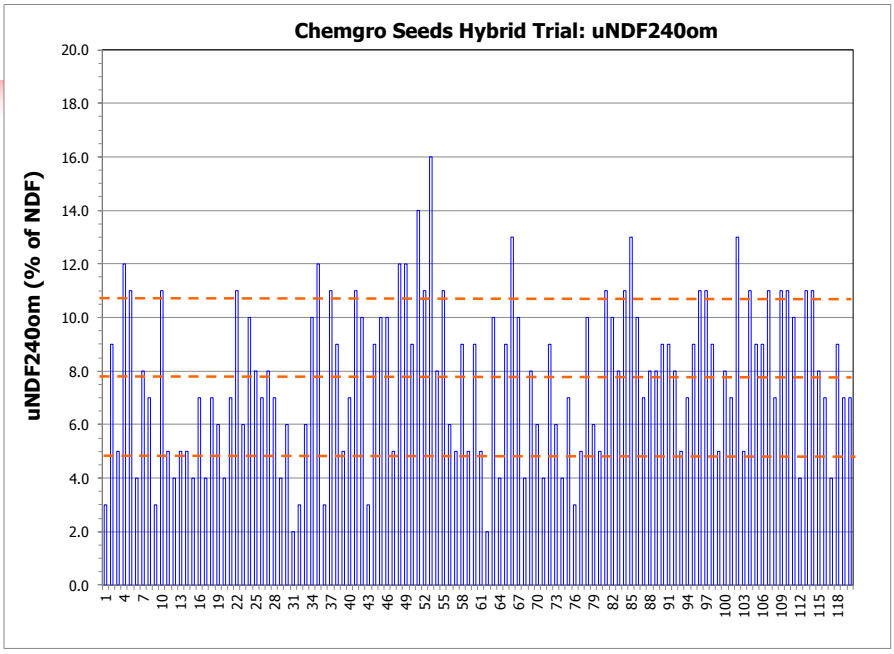
- **Corn silage**
  - 8.7% of DM
  - Range: 2.0 to 25.5%
  - iNDF k = 2.83
- **Legume silage**
  - 17.6% of DM
  - Range: 5.5 to 31.7%
  - iNDF k = 2.46
- **Grass silage**
  - 15.5% of DM
  - Range: 2.3 to 44.8%
  - iNDF k = 2.52

Tremendous variation in uNDF: need to capture when formulating diets and predicting cow response!

uNDF as a Hybrid Ranking Tool



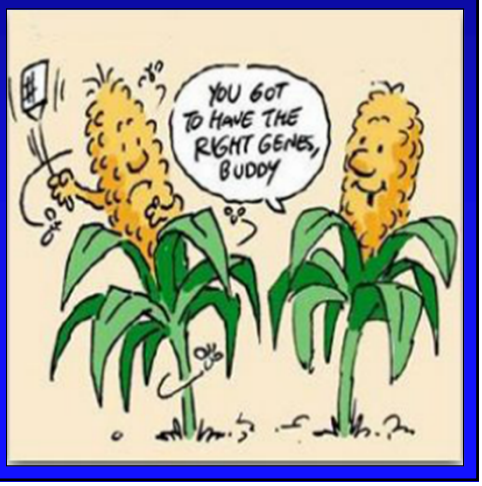
uNDF as a Hybrid Ranking Tool



Thank You!

What are GMO Crops and How Do We Talk About Them?

Margaret Smith
Plant Breeding & Genetics
Cornell University



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Topics

- Why the controversy?
- What is genetic engineering?
  - Context – previous crop genetic change
- What GE crops are grown? (and not grown!)
- What we know about big concerns

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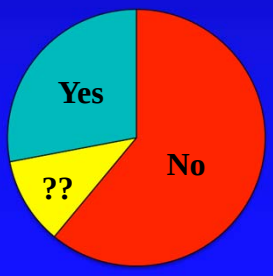
Why the Controversy?

- Genetic engineering - a logical extension of what plant breeders have always done
  - Little understanding of plant breeding
  - Have you ever eaten a fruit or vegetable that is a product of "traditional cross breeding"?



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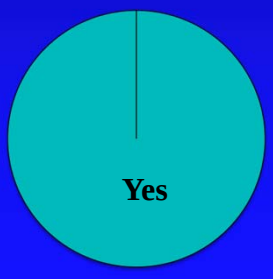

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Why the Controversy?

- Genetic engineering - a logical extension of what plant breeders have always done
  - Little understanding of plant breeding
  - Have you ever eaten a fruit or vegetable that is a product of "traditional cross breeding"?
- Most GE crops – benefits to consumers unclear
- New technology always raises concerns…

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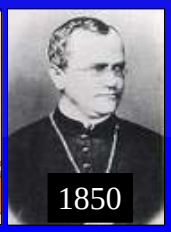
Genetic Engineering

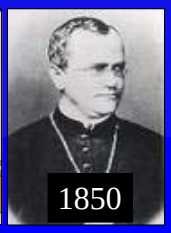
- A new tool for breeding improved crops

The watermelon, then and now. (Christie Images LTD 2015, Shutterstock)



Genetic Engineering

- A new tool for breeding improved crops
- Alters the properties of organisms by:
  - Moving single genes between organisms
  - Modifying a gene within an organism
- No need for sexual cross-compatibility…



Genetic Modifications Humans Have Made…

- Domestication
- Farmer selection of new crops and varieties
- Cross breeding
- Genetic engineering

"GMO" suggests that our crops were not genetically altered prior to use of genetic engineering…

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GE Crop Types Grown in the US

- Bt crops (corn, cotton, sweet corn)
- Herbicide resistant crops (soybean, corn, cotton, canola, sugar beet, alfalfa)
- Virus resistant crops (papaya, squash)

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What are "stacked" varieties?

- Two or more transgenes in one variety
- Insect resistance:

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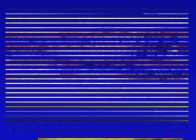
What are "stacked" varieties?

- Two or more transgenes in one variety
- Insect resistance:
  - Bt European corn borer
  - Bt corn rootworm
  - Bt general lepidoptera



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What are "stacked" varieties?

- Two or more transgenes in one variety
- Insect resistance:
  - Bt European corn borer
  - Bt corn rootworm
  - Bt general lepidoptera
- Herbicide tolerance:
  - Glyphosate (Roundup)
  - Glufosinate (Liberty)

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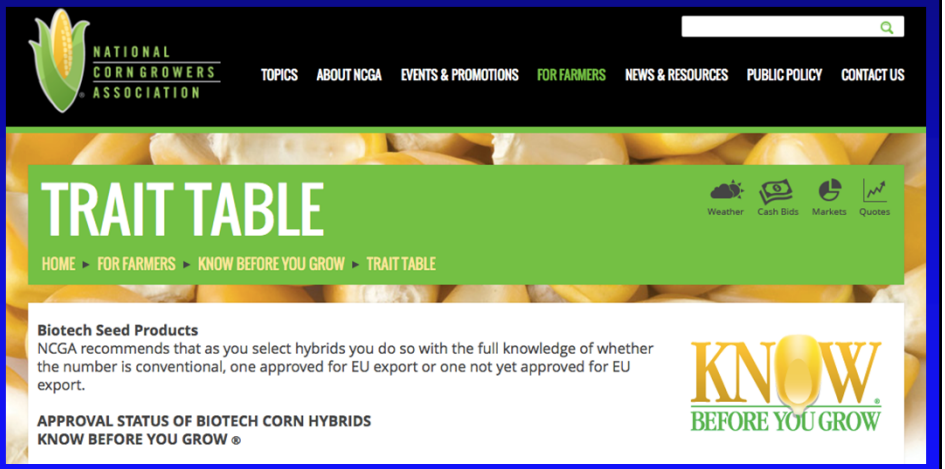
National Corn Growers Assoc.



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National Corn Growers Assoc.

Agrisure Duracade™ E-Z Refuge(TM) 5222

Characteristic: Cry1Ab, Corn Borer, Glufosinate herbicide Tolerance; Vip3A, European and Southwestern Corn Borers, Southern Cornstalk Borer, Fall and Beet Armyworm, Black and Western Bean Cutworm, Sugarcane Borer, Common Stalk borer and Dingy Cutworm protection; Cry1F, Western Bean Cutworm, Corn Borer, Black Cutworm and Fall Armyworm resistance; Cry3A-Cry1Ab, resistance to coleopteran and lepidopteran insects; Modified Cry3A, Protection of Western, Northern and Mexican Corn Rootworm; Glyphosate tolerance

Event: Bt11 X MIR162 X MIR604 X TC1507 X 5307 X GA21

Syngenta Agrisure™ CB/LL

Characteristic: Cry1Ab, Corn Borer, Glufosinate herbicide Tolerance

Event: Bt11

Purdue Corny News Network

PRODUCT REGISTRANT TRADE NAME	CHARACTERISTIC	EVENT	JAPAN APPROVED	EU FOOD APPROVAL	EU PROCESSED FEED APPROVAL
Syngenta Agrisure® CB/LL	Cry1Ab, Corn Borer protection. Glufosinate herbicide tolerance.	Bt11	Yes	Yes	Yes
DowAgrosciences Pioneer Hi-Bred Herculex® I	Cry1F, Western Bean Cutworm, Corn Borer, Black Cutworm and Fall Armyworm resistance Glufosinate herbicide tolerance.	TC1507	Yes	Yes	Yes
Monsanto YieldGard® Corn Borer	Cry1Ab, European and Southwestern Corn Borers, Sugarcane Borer and Southern Cornstalk Borer protection.	Mon 810	Yes	Yes	Yes
Monsanto YieldGard® Corn Borer with Roundup Ready® Corn 2	Cry1Ab, European and Southwestern Southwestern Corn Borers, Sugarcane Borer and Southern Cornstalk Borer protection. Glyphosate herbicide tolerance.	Mon 810 + Nk603	Yes	Yes	Yes
Monsanto YieldGard® Rootworm with Roundup Ready® Corn 2	Cry3Bb1, Western, Northern and Mexican Corn Rootworm Protection. Glyphosate herbicide tolerance.	Mon 863 + Nk603	Yes	Yes	Yes
Monsanto YieldGard® Rootworm	Cry3Bb1, Western, Northern and Mexican, Corn Rootworm protection. Glyphosate herbicide tolerance.	Mon 863	Yes	Yes	Yes
Monsanto Roundup Ready® Corn 2	Glyphosate herbicide tolerance.	NK603	Yes	Yes	Yes
Bayer CropScience LibertyLink®	Glufosinate herbicide tolerance.	T25	Yes	Yes	Yes

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https://www.agry.purdue.edu/ext/corn/news/timeless/biotechtraits.html

National Corn Growers Assoc.

Below is a table representing the single biotechnology events with limited approval status in major importing countries and the EU. (no = Possible Marketing Implications)

Single Event (Common Name)	Japan	Mexico	Canada	South Korea	China	Taiwan	E.U.
Event 5307 Duracade	yes	yes	yes	yes	no	yes	no
MIR 162 Viptera	yes	yes	yes	yes	yes	yes	yes
MON 87460 DroughtGard	yes	yes	yes	yes	yes	yes	yes
Event 3272 Enogen	yes	yes	yes	yes	yes	yes	no

If a trait is not listed here, it does not impact the major importing markets for U.S. corn.

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New Approved GE Crop Varieties

- More herbicide tolerances and insect resistances…
- Alfalfa – reduced lignin (Nov. 2014)
- Potato – reduced black spot bruise and low acrylamide production (Nov. 2014); also late blight resistant (Sept. 2015)
- Apple – non-browning (Feb. 2015)

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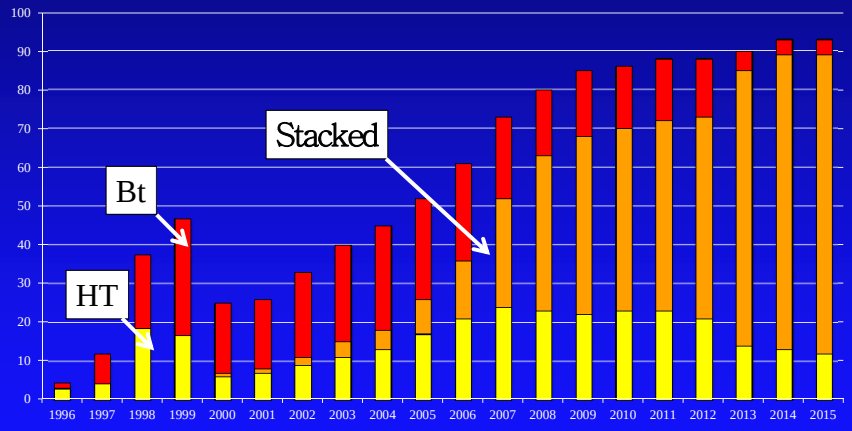
U.S. Corn Acreage Planted to GE Varieties, 1996 to 2015



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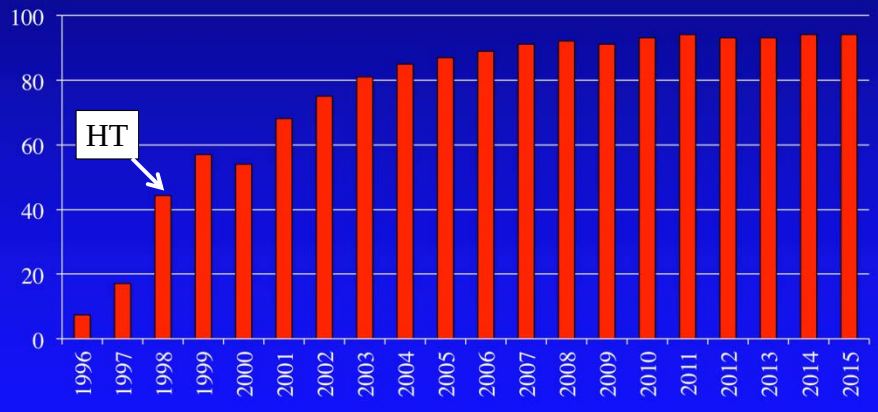
(data source: USDA ERS, 2015)

U.S. Soybean Acreage Planted to GE Varieties, 1996 to 2015



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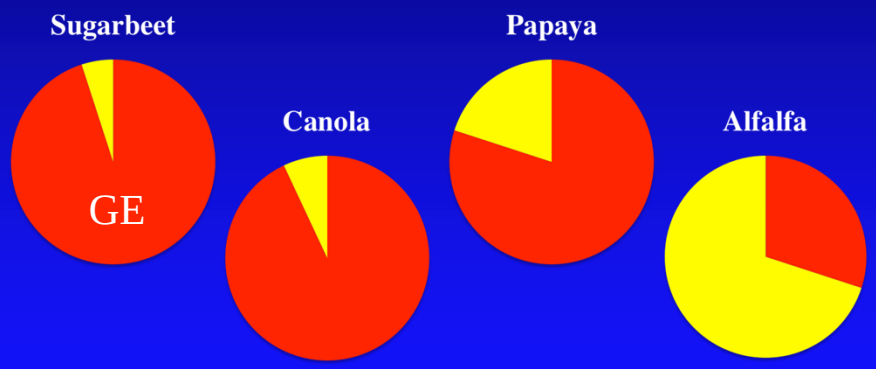
(data source: USDA ERS, 2015)

Estimates: U.S. Crop Acreage Planted to GE Varieties, 2014



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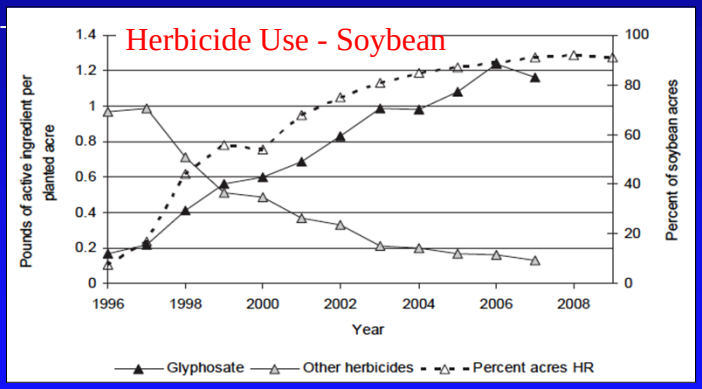
(data sources: Gonsalves 2014, GMO Compass 2013)

NAS – NRC Study Findings

- More herbicide used, but a less toxic one
  - Facilitated use of reduced tillage



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Weed Resistance to Roundup

Areas not growing GE crops:

7 weeds evolved resistance

1974 — 2009

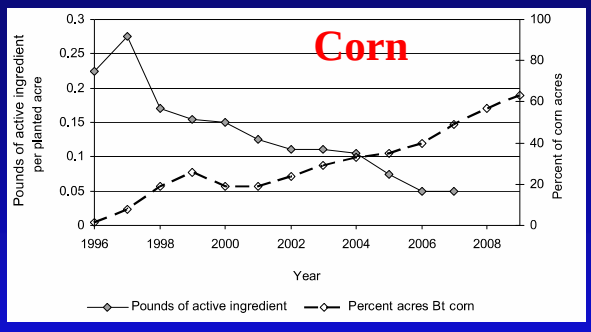
In U.S. since GE crops introduced:

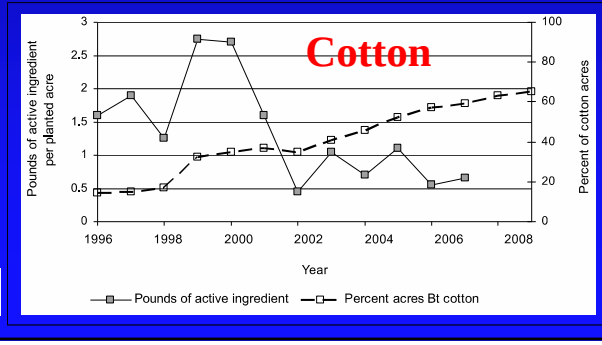
9 weeds evolved resistance

1996 — 2009

U.S. Insecticide Use per Acre is Down

Source:
NRC NAS 2010





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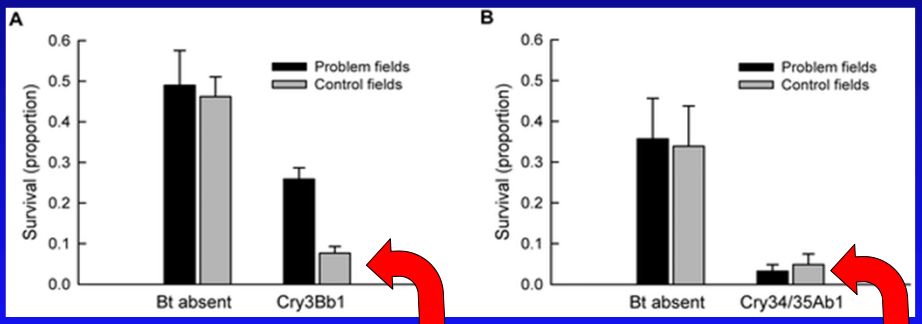
Survival of western corn rootworm on Bt and non-Bt maize



Cry3Bb1

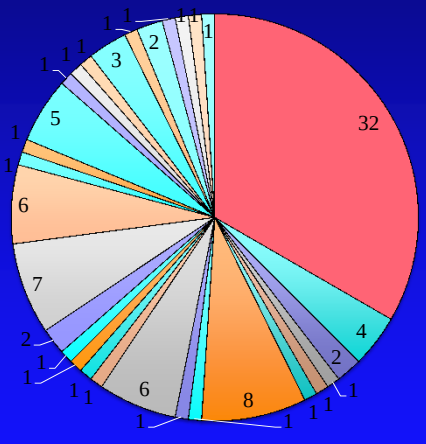
Cry34/35Ab1

Gassmann AJ, Petzold-Maxwell JL, Keweshan RS, Dunbar MW (2011) Field-Evolved Resistance to Bt Maize by Western Corn Rootworm. PLoS ONE 6(7): e22629. doi:10.1371/journal.pone.0022629
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0022629

PLoS one

Who Owns GE Traits? -originally

Total = 96



- Monsanto
- DeKalb
- Upjohn
- AgrEvo
- Plant Genetic Systems
- Novartis Seeds
- Northrup King
- Du Pont
- Dow AgroSciences
- Bejo
- Cornell University
- Florigene
- Okanagan
- U of Saskatchewan
- USDA/ARS
- Calgene
- Asgrow
- Aventis
- Agritope
- Syngenta
- Ciba-Geigy
- Zeneca & Petoseed
- Pioneer
- BASF
- Bayer
- DNA Plant Tech
- Mycogen
- Simplot
- University of Florida
- Vector Tobacco

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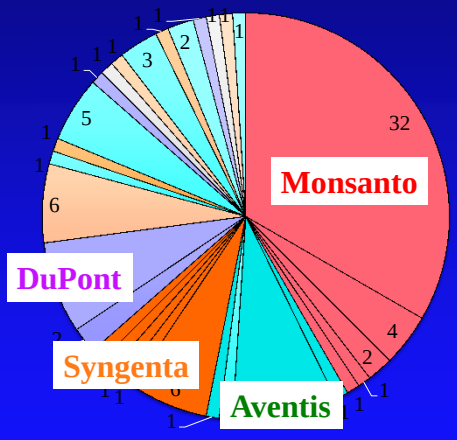
Who Owns GE Traits? – now…

Total = 96



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Who Owns GE Traits? – now…

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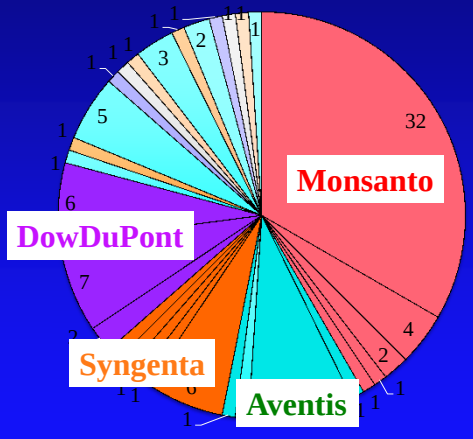

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Am I eating foods from genetically engineered crops?

(and are they safe???)

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What foods contain GE crops?

- 60-70% of supermarket foods have ingredients from a GE variety
- Products made with soy or corn most obvious
- Products with soy or corn derivatives
- Limited fresh produce

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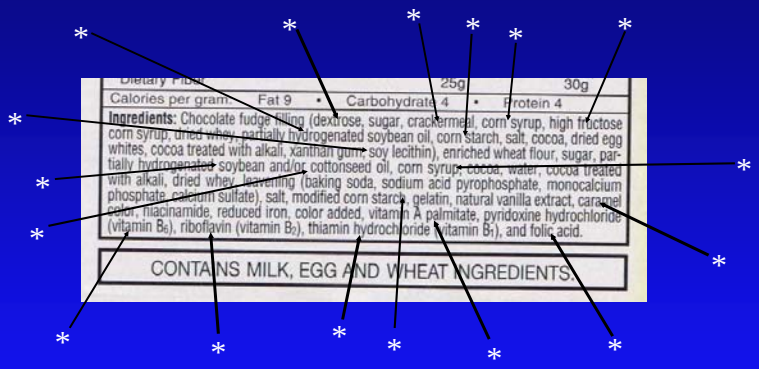
Food for Thought



* Ingredient may be made from a genetically-engineered organism

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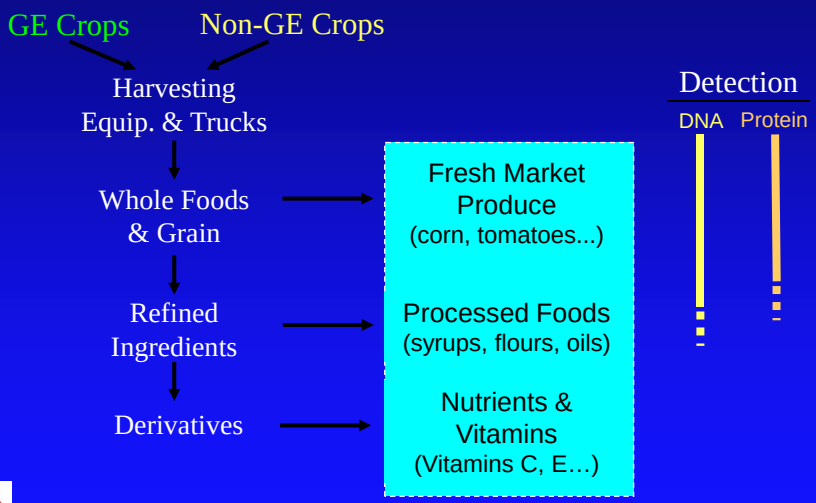
The Food Supply



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Are GE Crop Products Safe?

- Genetic Engineering Risk Atlas
  - 400+ studies, half were independently-funded
  - http://genera.biofortified.org/viewall.php
- 2014 summary of 1,783 studies
  - Safety as food, feed (770 studies)
  - Environmental impacts (847 studies)
- No credible evidence of safety concerns

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GENERA
GENetic Engineering Risk Atlas
A project of Biology Fortified, Inc.
beta

Summary

- A few major crops are sold as GE varieties
- Most people in the U.S. are eating foods that contain ingredients from a GE variety
  - Mostly highly refined ingredients with no novel DNA or protein left in them
- Produce: sweet corn, papaya, summer squash

Summary

- A few major crops are sold as GE varieties
- Most people in the U.S. are eating foods that contain ingredients from a GE variety
  - Mostly highly refined ingredients with no novel DNA or protein left in them

- Produce: sweet corn, papaya, summer squash
  - Coming: potato, apple ??

- Credible evidence to date shows they are safe as food and feed
  - Future products need to be evaluated

Breeding for corn silage yield and economics

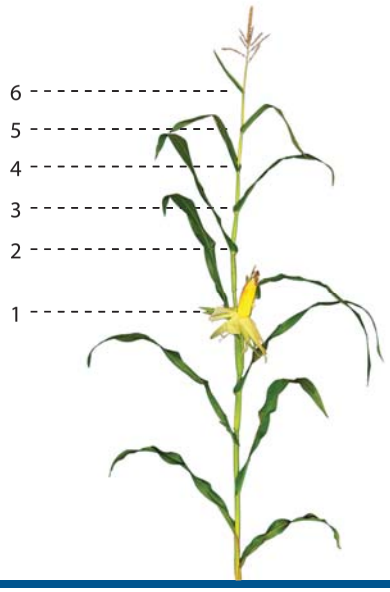
Dr. Francis Glenn

Miner Institute
Feb. 4, 2016

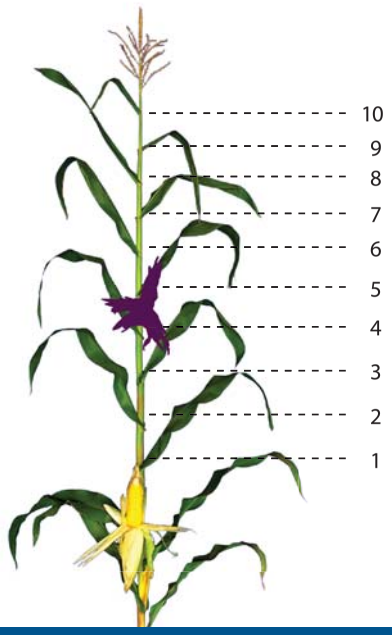
GLENN SEED
FEED CORN BREEDERS

	Corn Silage	Grain
Kernels	• Slow drying • Long harvest window • Breaks easily • Low test weight • Floury starch	• Fast drying • Short harvest window • Hard and intact • High test weight • Vitreous starch
Stalk	• Flexible • Digestible in rumen • Stand until silage harvest	• Strong and stiff • Long stay green • Stand until grain harvest

grain



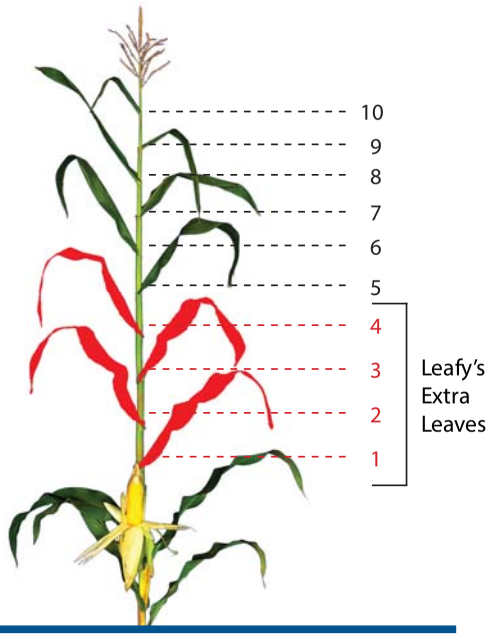
Leafy silage



Leafy silage

Leafy silage hybrids have 70% more *leaf area* above the ear per plant than dual-purpose grain hybrids.

Leafy silage hybrids have 40% more *total* leaf area per plant than dual-purpose grain hybrids.



Because of the 40% leaf area advantage, Leafy silage hybrids should be grown at a lower plant population of *28,000 ppa*.

State trials and farmer trials test silage hybrids at plant populations of 35,000 ppa.

35,000 ppa x 1.4 = 49,000 ppa

Planting Leafy at 35,000 ppa is the equivalent of growing a grain variety at 49,000 ppa!

Leafy Planted at 28,000

Produces a plant with a higher proportion of inner stalk to outer stalk. This increases fiber digestibility in the ration.

Produces a plant with a bigger ear and more total plant yield.

Stalks sliced at the same internode location of the plant. The inner stalk is more digestible (higher NDFd) than the outer stalk.

Five representative flex-type ears from each population density.

Comparison of the same hybrid at the same location planted at different populations.

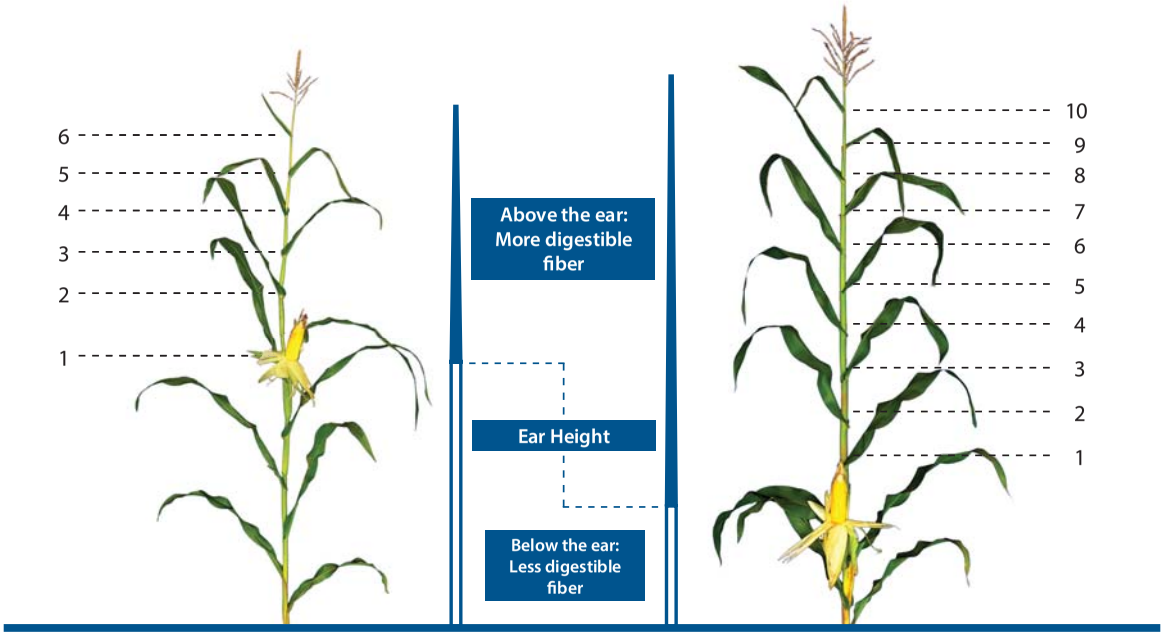
Leafy Planted at 35,000

Produces a plant with a higher proportion of outer stalk to inner stalk. This reduces fiber digestibility in the ration.

Produces a plant with a smaller ear and less total plant yield.

grain

Leafy silage



Rumen Starch Digestibility = Milk

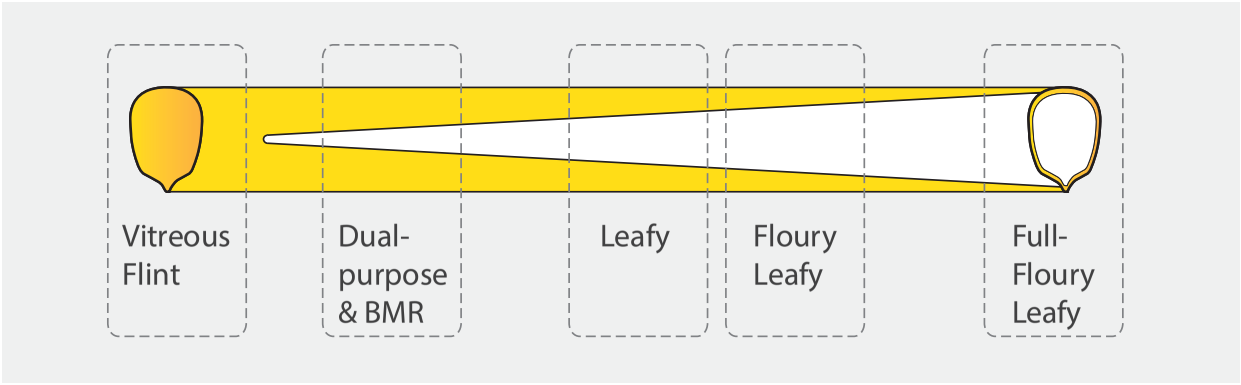
Rumen starch digestibility ↑ AS Starch particle size ↓

There are two ways to affect starch particle size:

1. Harvester

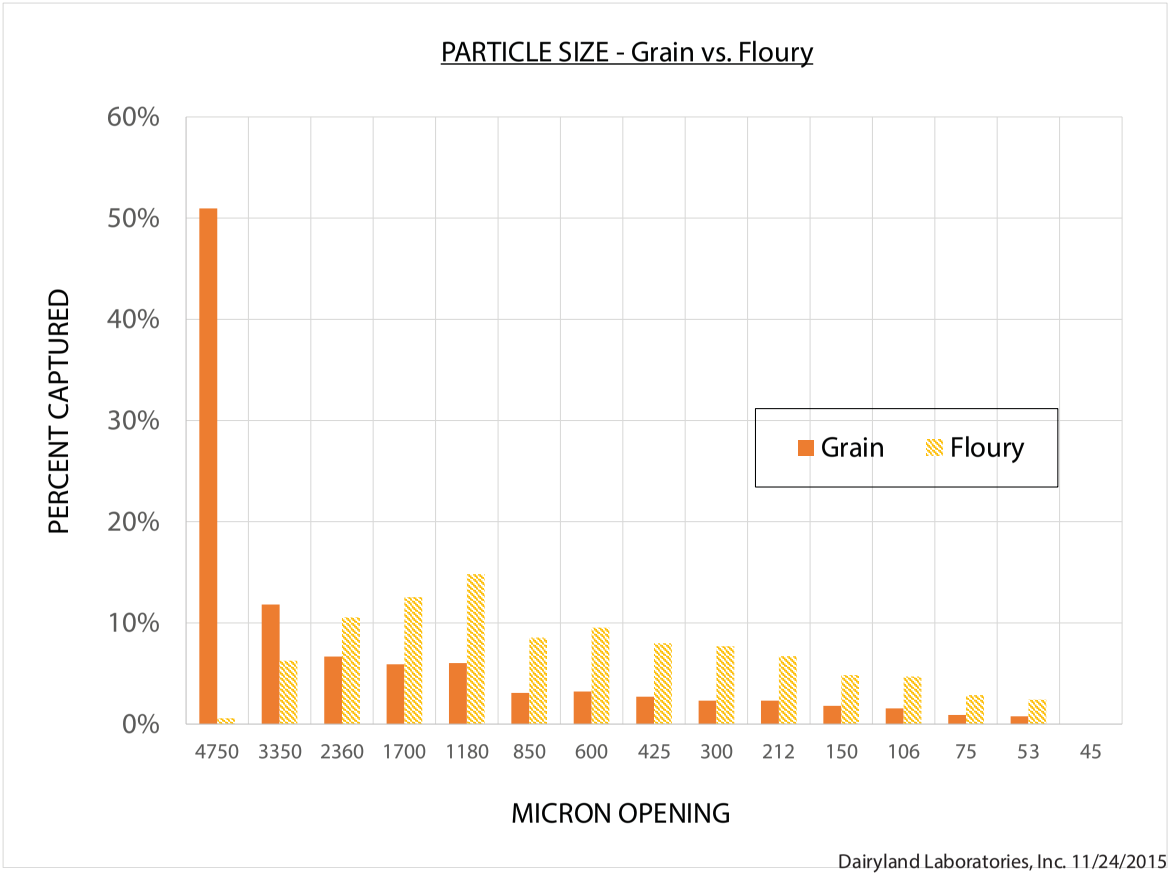
2. Genetics

- larger kernels
- more floury kernels
- slower drying kernels

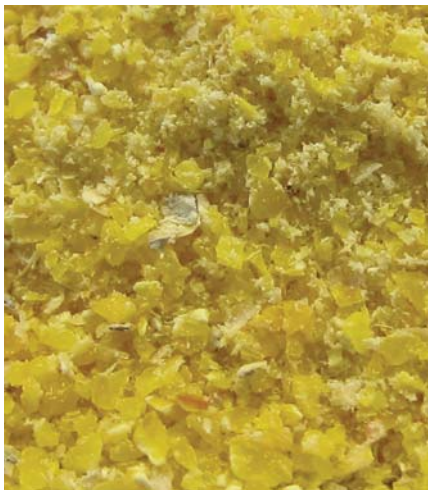


High Moisture Corn

- Soft kernels
- Slow drying
- Mold resistant
- High dry matter starch yield of digestible starch

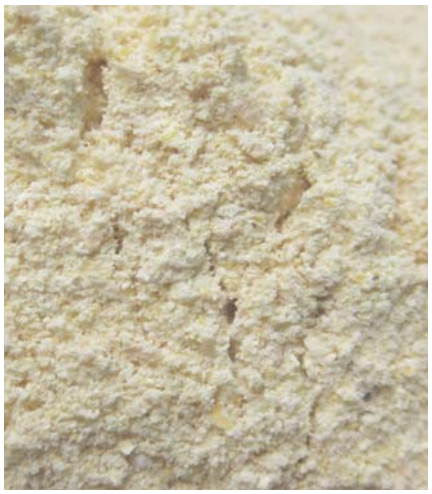


Can NIR detect floury starch?



Grain

Floury Leafy



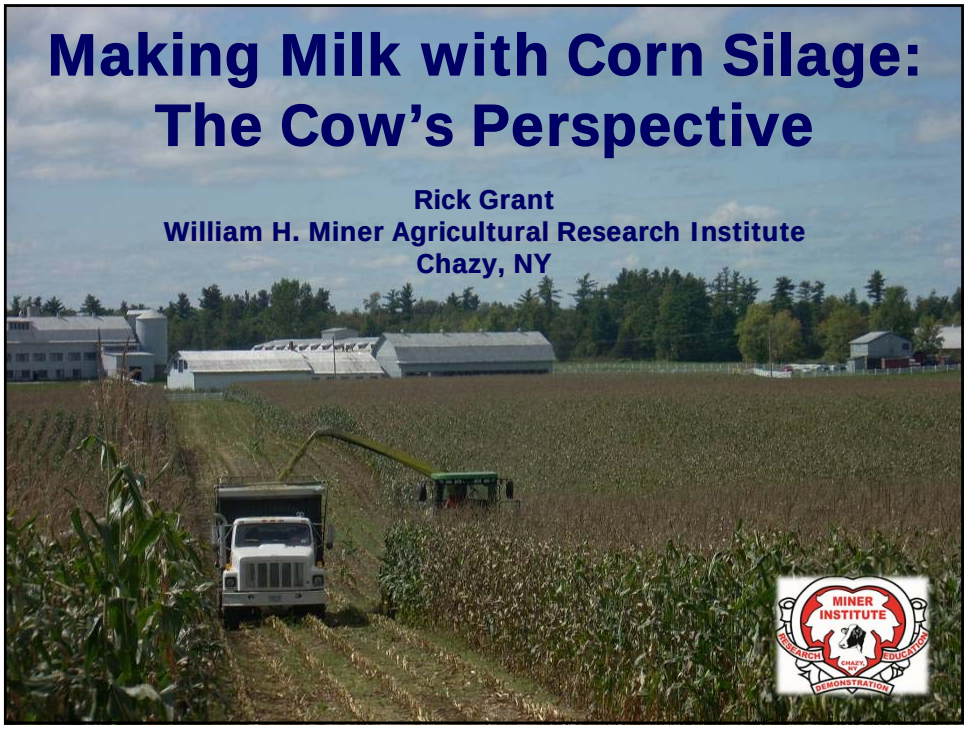
Full-Floury

For more information visit our
Glenn Seed Google+ page

"OK Google"
"Francis Glenn, corn breeder"

Making Milk with Corn Silage: The Cow's Perspective

Rick Grant
William H. Miner Agricultural Research Institute
Chazy, NY



Concepts to Understand

- NDF and NDF digestibility
- Give her time to eat
- Starch and starch digestibility
- CSPS – use it!
- Particle size – meh…
- SOL – maximizing her response

Forage NDF digestibility and cow performance

>40% corn silage in diet DM

- **For each 1%-unit increase in NDFD:**
- **+0.26 lb/d DMI**
- **+0.31 lb/d 3.5%FCM**

(Jung et al., 2010)

Measure NDF Digestibility and Indigestibility – Don't Fool Around with Lignin/ADF!

Measured NDFD or Estimation from Lignin?

NDF, %	Lignin, %	30-h NDFD
45.0	3.52	?
45.0	3.26	?
45.0	3.32	?
45.1	3.18	?
45.0	3.43	?

- Corn silage data set from Van Amburgh (2005)
- Similar relationships from 36.5 to 51.8% NDF

Measured NDFD or Estimation from Lignin?

NDF, %	Lignin, %	30-h NDFD
45.0	3.52	46.0
45.0	3.26	48.4
45.0	3.32	54.4
45.1	3.18	55.0
45.0	3.43	67.3

- Corn silage data set from Van Amburgh (2005)
- Similar relationships from 36.5 to 51.8% NDF

Undigested NDF: Latest forage quality measure

- uNDF to lignin ratio is highly variable and responsive to
  - genetics
  - maturity
  - growing conditions
- Becoming routine measurement for labs
- NIR prediction for uNDF better than ADL
- Suggest monitoring uNDF as benchmark of corn silage intake potential and digestibility

Measured ranges in uNDF240

(source: Dairy One, May, 2015 newsletter)

- Corn silage
  - 8.7% of DM
  - Range: 2.0 to 25.5%
- Legume silage
  - 17.6% of DM
  - Range: 5.5 to 31.7%
- Grass silage
  - 15.5% of DM
  - Range: 2.3 to 44.8%

Tremendous variation in uNDF that we need to capture when formulating diets and predicting cow response!

Interaction of Management Environment and Forage Digestibility

Forage NDF and time spent eating…

Item	Low CCS	High CCS	Low BMR	High BMR
	53% forage 40%CS:13% HCS	67% forage 54%CS:13% HCS	49% forage 36%BMR:13%HCS	64% forage 51%BMR:13%HCS
TMR NDF, % of DM	32.1	35.6	31.5	35.1
TMR 24-h NDFD, %	56.3	54.0	62.0	60.3
Eating Behavior				
Eating, h/d	4.6^{ab}	5.1^{a}	4.1^{b}	4.6^{b}
% of TCT	34.7	35.7	35.1	33.8

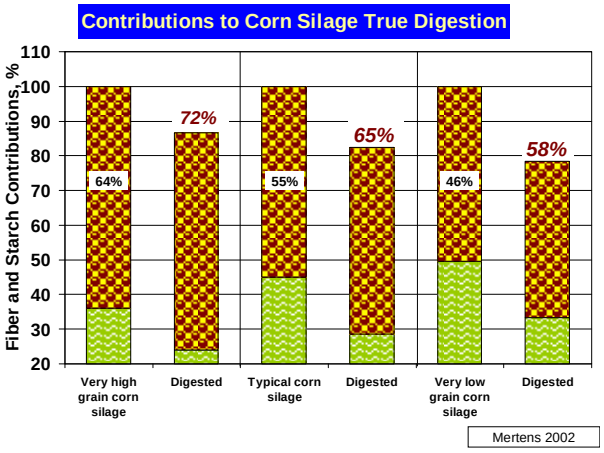
^{abc} Least squares means within a row without a common superscript differ ($P \leq 0.05$).

- Higher forage diets with slower fermenting forage-NDF take longer to process.
- Time budget challenge especially when overstocked at feed bunk or mixed parity pens.

Optimize starch digestibility of corn silage

- **<3% starch is goal**
- **1%-unit decrease in fecal starch results in 0.7 to 1.1 lb milk/day** (Firkins et al., 2001; Ferguson, 2006)

Importance of starch for corn silage digestibility (Owens, 2005)



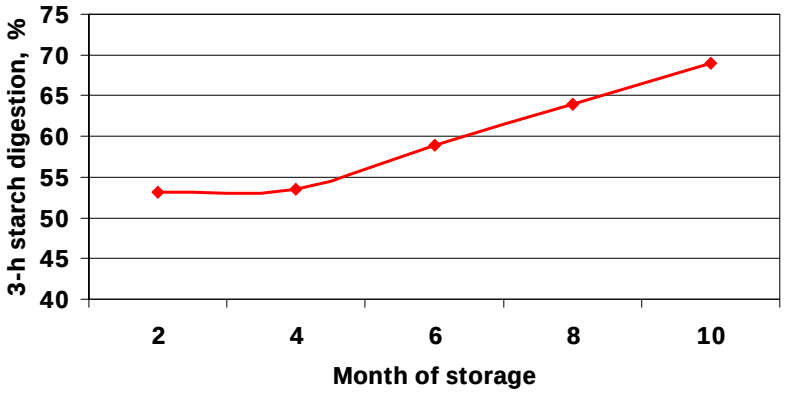
For typical corn silage ~65% of digested nutrients comes from starch

Starch is important!

Optimizing Silage Starch Digestibility

- To improve total tract starch digestibility, focus on:
  - Reducing grain particle size
    - How will you process the corn silage?
  - Greater moisture content of grain
    - 32-35% DM
  - Less vitreous endosperm
    - Keep an eye on new hybrids

Silage storage time and rumen starch digestibility



(Newbold et al., 2007)

Optimizing corn silage starch digestion

- **All kernels crushed, especially silage >33 to 35% DM**
- **0.75-in (19 mm) TLC, 2-3 mm roller clearance; Penn State Particle Separator**
  - **10-15% top screen**
  - **50+% second screen**
  - **<35% pan**
- **Corn silage processing score – use it!**

Corn Silage Processing Score

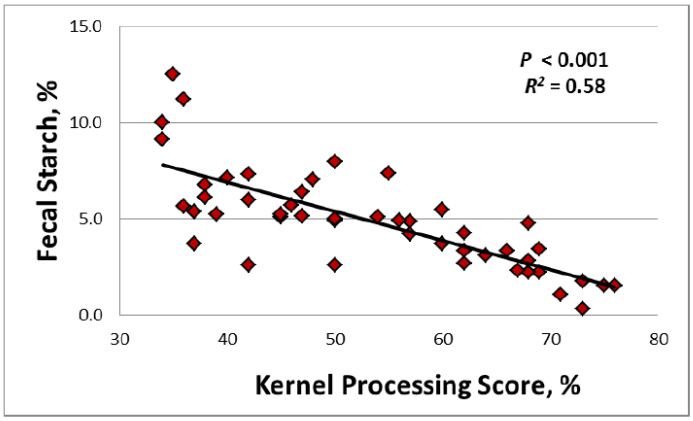
Corn silage processing score = % starch passing through 4.75-mm screen

- **>70% = optimal processing**
- **50-70% = average**
- **<50% = inadequate (too coarse)**

Photos: Dairy Land Labs

CSPS and fecal starch

(Braman and Kurtz, 2015)



Prediction equation: y = 12.90487 (± 1.04) - 0.15065x (±0.019)
y=fecal starch, % x= kernel processing score, %

Corn silage: A Case Study Dietary Ingredients

(Cotanch, March 2016 Farm Report)

	CS 2014	CS 2015	CS 2015 27% TMR starch
CS 2014, lb of DM	21.0	---	---
CS 2015, lb of DM	---	21.0	23.0
Haycrop silage, lb of DM	8.0	8.0	7.0
aNDF, % of DM	29.6	26.0	27.5
Starch, % of DM	26.2	30.2	27.8
peNDF, % of DM	21.3	18.6	19.8

CS 2014 and 2015 7-h starch digestibility = 83%

CS 2014 $\xrightarrow{7\ d}$ CS 2015 $\xrightarrow{7\ d}$ 50:50 $\xrightarrow{7\ d}$ CS 2015 (27% TMR starch)

Corn silage: A Case Study
Rumen pH hours < 5.8
(Cotanch, March 2016 Farm Report)

Cow ID #	CS 2014 26% TMR starch	CS 2015 30% TMR starch	CS 2015 27% TMR starch
1357	3.6	8.0	0.8
1842	4.1	6.9	5.0
2058	5.7	6.5	6.9
2347	0.02	0.4	0
Average pH < 5.8	3.4	5.5	3.2

Bottom line: starch amount and digestibility have large impact on ruminal pH ~ Don't guess at it - measure it!

Corn Silage Particle Size

- **Ferraretto and Shaver (2012) meta-analysis; 24 peer reviewed articles**
  - **TLOC range: 0.48 to >3.2 cm (0.18 to >1.25 in)**
  - **TLOC had minimal effect on DMI, milk yield, and digestibility**
- **Particle size has minimal impact on rumination and milk fat% in most studies.**

Cows varying in milk yield and stage of lactation vary greatly in response to corn silage digestibility!

High versus Low 48-h NDFd Corn Silage Hybrids

	Low NDFd	High NDFd
DM, %	36.2	35.7
CP, %	9.6	8.8
NDF, %	45.2	52.8
Starch, %	25.7	22.5
48-h NDFd	58	67

(Ivan et al., 2004)

Experimental Diets

(Ivan et al., 2004)

	Low NDFd	High NDFd
Alfalfa hay	10.0	10.0
Low NDFd CS	45.1	. . .
High NDFd CS	. . .	40.1
CP, % of DM	18.2	18.5
NDF, % of DM	30.8	30.8

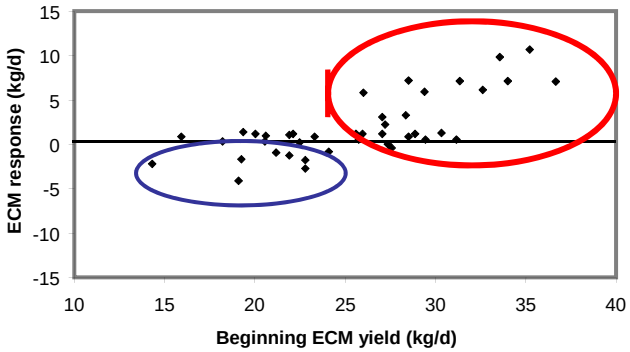
Milk Response: All Cows

	Low NDFd	High NDFd
DMI, lb/d	58.3	59.7
Milk, lb/d	76.3	78.3

- Is this all we get from improved NDF digestibility?

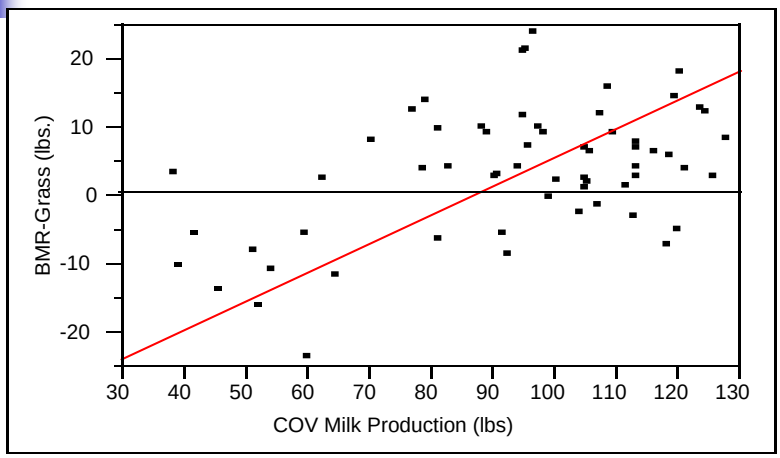
Response to high-NDFD corn silage by milk production level

(Ivan et al., 2004)



- **Allocate high NDFD forages to highest producing cows.**

Milk production level and response to bmr (24-h NDFD 56%) vs grass (24-h NDFD 53%; Miner Inst., 2008)



- **Mycogen F2F444 and 1st cut grass silage (ADF=32.5, NDF=51.1, CP=17.6%)**

Don’t Forget Fat …

- High corn silage and milk fat depression
  - Rapidly fermented starch
  - Low peNDF?
  - Amount and availability of C18:2
    - Sufficient to cause milk fat depression; consider hybrid and amount in diet (Harvatine, 2016)
    - 90 g/d variation based on normal CS hybrids

Concepts to Understand

- NDF and NDF digestibility
- Time budgets
- Starch and starch digestibility
- CSPS and starch use
- Particle size less important
- Properly allocate the silage

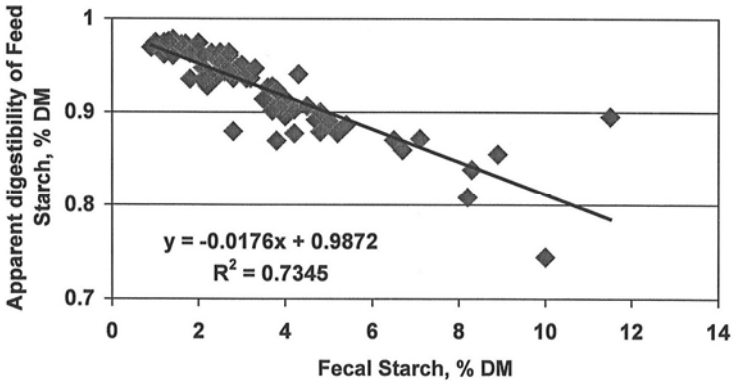
Useful Information …

Corn Grain Particle Size Recommendations

Sieve size, mm	% grain retained	
4.75	0	<45%, or else corn is too coarse
2.36	<10	
1.18	25-35	
0.60	50-60	
Pan	<15	

- If grain is too coarse, then you reduce its energy value; If it is too fine, you increase the risk of rumen acidosis.
- Penn State Particle Separator has 1.18-mm screen and can be used to assess corn grain particle size, or a common flour sifter usually has a screen which is ~1.18-mm.

Fecal starch and digestibility



- 4.5% fecal starch ~ 90% starch digestibility
- 1%-unit decrease in fecal starch ~ 1 pound more milk
- Range in starch: 2.3 – 22.4%

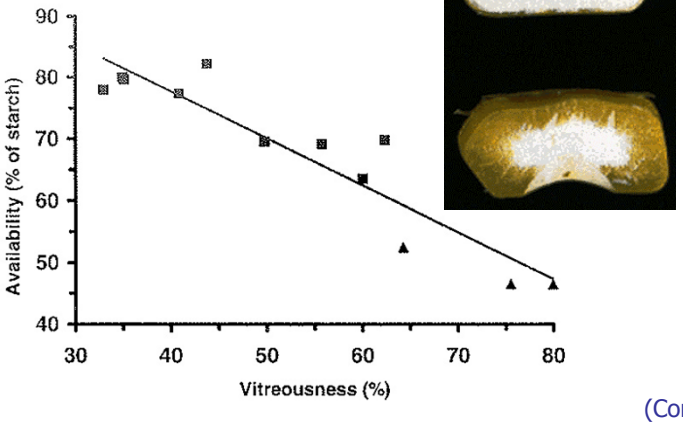
(Ferguson, 2006)

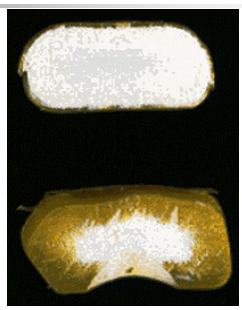
Important factors determining starch availability (Hoffman, 2008)

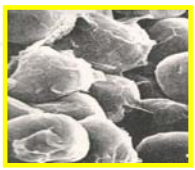
Factor	Correlation with starch availability
Particle size	-0.70
Moisture	-0.53
Endosperm type	-0.46

Grain particle size > Grain/silage moisture > Endosperm type

Vitreousness and rumen starch availability







(Correa et al., 2002)