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

The focus of most seed companies

Thomas, 2012
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

- Leafy has 8 or more leaves above the ear, which produce starch energy
- Large Flex Ear
- Large, Soft, Slow-drying Kernels
- Soft Digestible Cob

Ear Characteristics

Number of Above Ear Leaves

- 8
- 7
- 6
- 5
- 4
- 3
- 2
- 1

"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)
### What is an average hybrid?

<table>
<thead>
<tr>
<th>Trait</th>
<th>N</th>
<th>Forage yield</th>
<th>NDF</th>
<th>NDFD</th>
<th>Starch</th>
<th>Milk per Ton</th>
<th>Milk per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T/A</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>Lbs/T</td>
<td>Lbs/A</td>
</tr>
<tr>
<td>Bmr</td>
<td>56</td>
<td>6.2</td>
<td>48.3</td>
<td>68.4</td>
<td>26.3</td>
<td>3380</td>
<td>21300</td>
</tr>
<tr>
<td>CB</td>
<td>343</td>
<td>7.9</td>
<td>46.5</td>
<td>60.2</td>
<td>30.5</td>
<td>3260</td>
<td>25600</td>
</tr>
<tr>
<td>CB, LL</td>
<td>142</td>
<td>7.9</td>
<td>46.6</td>
<td>60.2</td>
<td>30.5</td>
<td>3250</td>
<td>25700</td>
</tr>
<tr>
<td>CB, RR</td>
<td>161</td>
<td>7.8</td>
<td>46.1</td>
<td>60.0</td>
<td>31.4</td>
<td>3270</td>
<td>25600</td>
</tr>
<tr>
<td>CB,CR,RR</td>
<td>171</td>
<td>7.8</td>
<td>46.1</td>
<td>59.9</td>
<td>31.2</td>
<td>3270</td>
<td>25400</td>
</tr>
<tr>
<td>Leafy</td>
<td>96</td>
<td>7.8</td>
<td>48.2</td>
<td>59.3</td>
<td>27.5</td>
<td>3190</td>
<td>24900</td>
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<tr>
<td>RR</td>
<td>125</td>
<td>7.6</td>
<td>47.0</td>
<td>59.4</td>
<td>30.2</td>
<td>3220</td>
<td>24500</td>
</tr>
<tr>
<td>Normal</td>
<td>1304</td>
<td>7.6</td>
<td>47.1</td>
<td>60.0</td>
<td>29.7</td>
<td>3230</td>
<td>24500</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td></td>
<td>0.8</td>
<td>2.7</td>
<td>1.8</td>
<td>3.9</td>
<td>110</td>
<td>250</td>
</tr>
<tr>
<td>Average</td>
<td>2665</td>
<td>8.0</td>
<td>46.7</td>
<td>59.8</td>
<td>30.6</td>
<td>3240</td>
<td>26000</td>
</tr>
</tbody>
</table>

### 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**
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

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

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

REFERENCES:
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

Yield at 35% dry matter (tons/acre)

Hybrid number

Yield at 35% dry matter (tons/ac) 

P = 0.46
Harvest Moisture

Starch Content

Hybrid number

Dry matter content (%)

Starch content (% of DM)

Hybrid number

Starch content (% DM)

$P = 0.61$
7-hr Starch Digestibility

Lignin Content
Neutral Detergent Fiber

Neutral Detergent Fiber (aNDFom (% DM))

Hybrid number

P = 0.12

30-hr NDF Digestibility

30-hr NDF Digestibility (aNDFd30om (% of aNDFd30om))

Hybrid number

P = 0.009
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

![Graph showing 30-hr undigested NDF (% of aNDF30om) across different hybrid numbers. The graph includes error bars and letter annotations indicating statistical significance. The legend states: P = 0.0009.]
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?

- 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

Cotanch, 2016
What’s Undigested NDF?

From Cotanch, 2015

![Image showing undigested NDF in corn silage samples]

<table>
<thead>
<tr>
<th>Fast Pools</th>
<th>Slow Pools</th>
</tr>
</thead>
<tbody>
<tr>
<td>High NDFD</td>
<td>Low NDFD</td>
</tr>
</tbody>
</table>

NDF, % Remaining

Time, h

0 50 100 150 200 250 300

uNDF240
**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

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**BMR and non-BMR uNDF**

![Graph showing % Remaining over Time](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%
  - \( i\text{NDF} \) \( k = 2.83 \)

- **Legume silage**
  - 17.6% of DM
  - Range: 5.5 to 31.7%
  - \( i\text{NDF} \) \( k = 2.46 \)

- **Grass silage**
  - 15.5% of DM
  - Range: 2.3 to 44.8%
  - \( i\text{NDF} \) \( k = 2.52 \)

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

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uNDF as a Hybrid Ranking Tool

![Chemgro Seeds Hybrid Trial: uNDF30om](image)

...
uNDF as a Hybrid Ranking Tool

Chemgro Seeds Hybrid Trial: uNDF240om

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

Margaret Smith
Plant Breeding & Genetics
Cornell University

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
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 students responded "Yes".
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…

Genetic Engineering

• A new tool for breeding improved crops

9000 yr. ago  1850  1929  2000
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…

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)
What are “stacked” varieties?

• Two or more transgenes in one variety
• Insect resistance:
  – Bt European corn borer
  – Bt corn rootworm
  – Bt general lepidoptera
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)
Agrisure Duracade™ E-Z Refuge(TM) 5222

Characteristics: 
- Cry1Ab, Corn Borer, Glufosinate herbicide tolerance; Vip3A, European and Southwestern Corn Borer, Southern Cornstalk Borer, Fall Armyworm and Black and Western Bean Cutworm, Sugarcane Borer, Common Stalk borers 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

Characteristics: Cry1Ab, Corn Borer, Glufosinate herbicide tolerance

Event: Bt11

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<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>TRADING NAME</th>
<th>CHARACTERISTIC</th>
<th>EVENT</th>
<th>JAPAN APPROVAL</th>
<th>EU FOOD APPROVAL</th>
<th>EU PROCESSED APPROVAL</th>
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</thead>
<tbody>
<tr>
<td>Syngenta Agrisure CB/LL</td>
<td>Cry1Ab, Corn Borer protection, Glufosinate herbicide tolerance</td>
<td>Bt11</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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<tr>
<td>DowAgroSciences</td>
<td>Monarch (B17</td>
<td>Cry2Ab, Western Bean, Corn Borer, Black Cutworm and Fall Armyworm resistance; Glufosinate herbicide tolerance</td>
<td>TC1507</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Monsanto YieldGard</td>
<td>Corn Borer with Roundup Ready 2 Corn 2</td>
<td>Cry1Ab, European and Southwestern Corn Borer, Sugarcane Borer and Southern Cornstalk Borer protection.</td>
<td>Mon 810</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Monsanto YieldGard</td>
<td>Corn Borer with Roundup Ready 2 Corn 2</td>
<td>Cry2Ab, European and Southwestern Corn Borer, Sugarcane Borer and Southern Cornstalk Borer protection.</td>
<td>Mon 810 + Nis803</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
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<td>Corn Borer with Roundup Ready 2 Corn 2</td>
<td>Cry2Ab, European and Southwestern Corn Borer, Sugarcane Borer and Southern Cornstalk Borer protection.</td>
<td>Mon 810 + Nis803</td>
<td>Yes</td>
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<td>Pioneer Hi-Bred</td>
<td>Pioneer Hi-Bred</td>
<td>Glyphosate resistant corn</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Syngenta Proof</td>
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<td>Glyphosate resistant corn</td>
<td>Mon 865</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
</table>

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)
U.S. Corn Acreage Planted to GE Varieties, 1996 to 2015
(data source: USDA ERS, 2015)

U.S. Soybean Acreage Planted to GE Varieties, 1996 to 2015
(data source: USDA ERS, 2015)
Estimates: U.S. Crop Acreage Planted to GE Varieties, 2014

(data sources: Gonsalves 2014, GMO Compass 2013)

NAS – NRC Study Findings
- More herbicide used, but a less toxic one
  - Facilitated use of reduced tillage

Herbicide Use - Soybean
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

Graphs showing the decrease in insecticide use per acre for Corn and Cotton.
Survival of western corn rootworm on Bt and non-Bt maize


http://www.plosone.org/article/info:doi/10.1371/journal.pone.0022629

Who Owns GE Traits? –originally

Total = 96

- Monsanto
- DeKalb
- Upjohn
- AgrEvo
- Plant Genetic Systems
- Novartis Seeds
- Northrup King
- DuPont
- Dow AgroSciences
- Bejo
- Cornell University
- Florigene
- Okanagan
- U of Saskatchewan
- USDA/ARS
- Calgene
- Aventis
- Syngenta
- Ciba-Geigy
- Zeneca & Petoseed
- Pioneer
- BASF
- Bayer
- DNA Plant Tech
- Myogen
- Simplot
- University of Florida
- Vector Tobacco
Who Owns GE Traits? – now...

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

Total = 96
Am I eating foods from genetically engineered crops?
(and are they safe???)

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
Food for Thought

* Ingredient may be made from a genetically-engineered organism

**The Food Supply**

GE Crops

Non-GE Crops

Harvesting Equip. & Trucks

Whole Foods & Grain

Refined Ingredients

Derivatives

Fresh Market Produce (corn, tomatoes...)

Processed Foods (syrups, flours, oils)

Nutrients & Vitamins (Vitamins C, E...)

Detection

DNA Protein
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

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

Thank you!
Breeding for corn silage yield and economics

Dr. Francis Glenn
Miner Institute
Feb. 4, 2016
<table>
<thead>
<tr>
<th>Corn Silage</th>
<th>Grain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leafy silage</strong></td>
<td><strong>Stalk</strong></td>
</tr>
<tr>
<td>Flexible</td>
<td>Digestible in rumen</td>
</tr>
<tr>
<td>Long stay green</td>
<td>Stand until silage harvest</td>
</tr>
<tr>
<td>Strong and stiff</td>
<td>Stand until grain harvest</td>
</tr>
<tr>
<td>Vitreous starch</td>
<td>High test weight</td>
</tr>
<tr>
<td>Slow drying</td>
<td>Short harvest window</td>
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<tr>
<td>Breaks easily</td>
<td>Hard and intact</td>
</tr>
<tr>
<td>Low test weight</td>
<td>Flowery starch</td>
</tr>
<tr>
<td>Floury starch</td>
<td>Fast drying</td>
</tr>
</tbody>
</table>

1. Leafy silage
2. Stalk
3. Corn Silage
4. Grain
5. Slow drying
6. Breaks easily
7. Low test weight
8. Flowery starch
9. Fast drying
10. Hard and intact
11. High test weight
12. Vitreous starch

- Stand until silage harvest
- Stand until grain harvest
Leafy silage hybrids have 70% more leaf area above the ear 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.

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

$35,000 \text{ ppa} \times 1.4 = 49,000 \text{ ppa}$
Leaky silage

- Leafy Planted at 28,000
- Leafy Planted at 35,000

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.

- 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 higher proportion of inner stalk to outer stalk. This increases fiber digestibility in the ration.

Comparison of the same hybrid at the same location planted at different population densities.

Ear Height

1. Leaky silage
2. Grain

Below the ear:
- More digestible fiber

Above the ear:
- Less digestible fiber

Ear Height

Leafy planted at 35,000

Leafy planted at 28,000

Ear Height

Ear Height

Ear Height

Ear Height

Ear Height

Ear Height
Rumen starch digestibility

Starch particle size

Rumen Starch Digestibility = Milk
There are two ways to affect starch particle size:

1. Harvester
   - Larger kernels
   - More floury kernels
   - Slower drying kernels

2. Genetics
   - Leafy Floury
   - Full-Floury
   - Leafy
   - Vitreous
   - BMR
   - Dual-purpose
   - Flint
   - Leafy Floury
   - Leafy

2. Genetics
High Moisture Corn

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

PARTICLE SIZE - Grain vs. Floury

<table>
<thead>
<tr>
<th>Micron Opening</th>
<th>4750</th>
<th>3350</th>
<th>2360</th>
<th>1700</th>
<th>1180</th>
<th>850</th>
<th>600</th>
<th>425</th>
<th>300</th>
<th>212</th>
<th>150</th>
<th>106</th>
<th>75</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERCENT CAPTURED</td>
<td>0%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
<td>50%</td>
<td>60%</td>
<td>70%</td>
<td>80%</td>
<td>90%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dairyland Laboratories, Inc. 11/24/2015
Can NIR detect floury starch?

For more information visit our Glenn Seed Google+ page

“Francis Glenn, corn breeder”
“OK Google”

Grain

Full-Floury

Floury Leafy
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

• For each 1% 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?

<table>
<thead>
<tr>
<th>NDF, %</th>
<th>Lignin, %</th>
<th>30-h NDFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.0</td>
<td>3.52</td>
<td>?</td>
</tr>
<tr>
<td>45.0</td>
<td>3.26</td>
<td>?</td>
</tr>
<tr>
<td>45.0</td>
<td>3.32</td>
<td>?</td>
</tr>
<tr>
<td>45.1</td>
<td>3.18</td>
<td>?</td>
</tr>
<tr>
<td>45.0</td>
<td>3.43</td>
<td>?</td>
</tr>
</tbody>
</table>

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

## Measured NDFD or Estimation from Lignin?

<table>
<thead>
<tr>
<th>NDF, %</th>
<th>Lignin, %</th>
<th>30-h NDFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.0</td>
<td>3.52</td>
<td>46.0</td>
</tr>
<tr>
<td>45.0</td>
<td>3.26</td>
<td>48.4</td>
</tr>
<tr>
<td>45.0</td>
<td>3.32</td>
<td>54.4</td>
</tr>
<tr>
<td>45.1</td>
<td>3.18</td>
<td>55.0</td>
</tr>
<tr>
<td>45.0</td>
<td>3.43</td>
<td>67.3</td>
</tr>
</tbody>
</table>

- 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 uNDF_{240} (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...

<table>
<thead>
<tr>
<th>Item</th>
<th>Low CCS</th>
<th>High CCS</th>
<th>Low BMR</th>
<th>High BMR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>53% forage 40%CS:13% HCS</td>
<td>67% forage 54%CS:13% HCS</td>
<td>49% forage 36%BMR:13%HCS</td>
<td>64% forage 51%BMR:13%HCS</td>
</tr>
<tr>
<td>TMR NDF, % of DM</td>
<td>32.1</td>
<td>35.6</td>
<td>31.5</td>
<td>35.1</td>
</tr>
<tr>
<td>TMR 24-h NDFD, %</td>
<td>56.3</td>
<td>54.0</td>
<td>62.0</td>
<td>60.3</td>
</tr>
<tr>
<td>Eating Behavior</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating, h/d</td>
<td>4.6&lt;sup&gt;a&lt;/sup&gt;b</td>
<td>5.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>% of TCT</td>
<td>34.7</td>
<td>35.7</td>
<td>35.1</td>
<td>33.8</td>
</tr>
</tbody>
</table>

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)
CSPS and fecal starch
(Braman and Kurtz, 2015)

\[
P < 0.001 \\
R^2 = 0.58
\]

Fecal Starch, %

Kernel Processing Score, %

Prediction equation: \( y = 12.96487 (\pm 1.04) - 0.150066x (\pm 0.019) \)

\( y = \) fecal starch, %  \( x = \) kernel processing score, %

---

Corn silage: A Case Study
Dietary Ingredients
(Cotanch, March 2016 Farm Report)

<table>
<thead>
<tr>
<th></th>
<th>CS 2014</th>
<th>CS 2015</th>
<th>CS 2015 27% TMR starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 2014, lb of DM</td>
<td>21.0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>CS 2015, lb of DM</td>
<td>---</td>
<td>21.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Haycrop silage, lb of DM</td>
<td>8.0</td>
<td>8.0</td>
<td>7.0</td>
</tr>
<tr>
<td>aNDF, % of DM</td>
<td>29.6</td>
<td>26.0</td>
<td>27.5</td>
</tr>
<tr>
<td>Starch, % of DM</td>
<td>26.2</td>
<td>30.2</td>
<td>27.8</td>
</tr>
<tr>
<td>peNDF, % of DM</td>
<td>21.3</td>
<td>18.6</td>
<td>19.8</td>
</tr>
</tbody>
</table>

CS 2014 and 2015 7-h starch digestibility = 83%
Corn silage: A Case Study
Rumen pH hours < 5.8
(Cotanch, March 2016 Farm Report)

<table>
<thead>
<tr>
<th>Cow ID #</th>
<th>CS 2014 26% TMR starch</th>
<th>CS 2015 30% TMR starch</th>
<th>CS 2015 27% TMR starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1357</td>
<td>3.6</td>
<td>8.0</td>
<td>0.8</td>
</tr>
<tr>
<td>1842</td>
<td>4.1</td>
<td>6.9</td>
<td>5.0</td>
</tr>
<tr>
<td>2058</td>
<td>5.7</td>
<td>6.5</td>
<td>6.9</td>
</tr>
<tr>
<td>2347</td>
<td>0.02</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Average pH &lt; 5.8</td>
<td>3.4</td>
<td>5.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

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!

<table>
<thead>
<tr>
<th></th>
<th>Low NDFd</th>
<th>High NDFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, %</td>
<td>36.2</td>
<td>35.7</td>
</tr>
<tr>
<td>CP, %</td>
<td>9.6</td>
<td>8.8</td>
</tr>
<tr>
<td>NDF, %</td>
<td>45.2</td>
<td>52.8</td>
</tr>
<tr>
<td>Starch, %</td>
<td>25.7</td>
<td>22.5</td>
</tr>
<tr>
<td>48-h NDFd</td>
<td>58</td>
<td>67</td>
</tr>
</tbody>
</table>

(Ivan et al., 2004)
## Experimental Diets
(Ivan et al., 2004)

<table>
<thead>
<tr>
<th></th>
<th>Low NDFd</th>
<th>High NDFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa hay</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Low NDFd CS</td>
<td>45.1</td>
<td>...</td>
</tr>
<tr>
<td>High NDFd CS</td>
<td>...</td>
<td>40.1</td>
</tr>
<tr>
<td>CP, % of DM</td>
<td>18.2</td>
<td>18.5</td>
</tr>
<tr>
<td>NDF, % of DM</td>
<td>30.8</td>
<td>30.8</td>
</tr>
</tbody>
</table>

## Milk Response: All Cows

<table>
<thead>
<tr>
<th></th>
<th>Low NDFd</th>
<th>High NDFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lb/d</td>
<td>58.3</td>
<td>59.7</td>
</tr>
<tr>
<td>Milk, lb/d</td>
<td>76.3</td>
<td>78.3</td>
</tr>
</tbody>
</table>

—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

<table>
<thead>
<tr>
<th>Sieve size, mm</th>
<th>% grain retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>0</td>
</tr>
<tr>
<td>2.36</td>
<td>&lt;10</td>
</tr>
<tr>
<td>1.18</td>
<td>25-35</td>
</tr>
<tr>
<td>0.60</td>
<td>50-60</td>
</tr>
<tr>
<td>Pan</td>
<td>&lt;15</td>
</tr>
</tbody>
</table>

- 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 a 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)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Correlation with starch availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size</td>
<td>-0.70</td>
</tr>
<tr>
<td>Moisture</td>
<td>-0.53</td>
</tr>
<tr>
<td>Endosperm type</td>
<td>-0.46</td>
</tr>
</tbody>
</table>

Grain particle size > Grain/silage moisture > Endosperm type

Vitreousness and rumen starch availability (Correa et al., 2002)