Corn silage for Dairy Cattle: Past, Present & Future

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Mention of companies, labs, trade names, products or assays solely for the purpose of providing specific information or examples and does not imply recommendation, endorsement or exclusion.
Corn Silage’s Past
(30-35 years ago)

• “Well-eared” 51% NDF in (US Canadian Feed Tables, 1982) & “Normal” 45% ± 5% NDF in (Dairy NRC, 2001 Feed Tables)
• No Corn Silage hybrid selection programs
• Neither starch nor ivNDFD assayed by commercial labs
• At least for Wisconsin, generally
  • Worst fields of corn chopped for silage
  • Targeted to replacement heifers and dry cows
  • Only up to 25% of forage DM if fed to milking cows
• Fine chopping (1/4th-3/8th” or 6-10 mm TLOC)
  • No kernel processing
  • No peNDF focus
• Use of uprights so tendency to chop drier (>40% DM)
• Very limited use of microbial inoculants
Today's Corn Silage

• 41% ± 5% NDF, 54% ± 5% ivNDFD₃₀, 32% ± 7% Starch
• Corn Silage hybrid selection programs with Starch, ivNDFD, & Quality Index focus
• BMR & other “silage specific” commercial hybrids
• Starch, ivNDFD, & uNDF assayed by commercial labs
• Predominant forage in milking cows rations
• Kernel processing the norm
  • StarchD focus
  • Longer chop lengths (3/4”-1” or 19-26 mm TLOC)
    • peNDF focus
• Custom harvesters more the norm
• Horizontal silos, 35% harvest DM target, & use of microbial inoculants typical
Whole-Plant Corn Silage

Grain ~40-45% of WPDM
- Avg. 32% starch in WPDM
- Variable grain:stover

Stover= ~55-60% of WPDM
- Avg. 41% NDF in WPDM
- Variable stover:grain

80 to 98% StarchD
- Processing, particle size
- Fermentation
- Maturity
- Endosperm properties
- Additives (exp.)

40 to 70% TVNDFD
- Lignin/NDF
  - Hybrid Type
  - Environment; G × E
  - Maturity
- Cutting height
- Additives (exp.)

Variable peNDF as per chop length

Adapted from Joe Lauer, UW Madison Agronomy Dept.
## Corn Silage Quality Indicators for High-Producing Dairy Herds

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indicates Better Quality</th>
<th>Primary Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF</td>
<td>▼</td>
<td>▼ Rumen Fill Limitation of DMI</td>
</tr>
<tr>
<td>Lignin</td>
<td>▼</td>
<td></td>
</tr>
<tr>
<td>uNDF$_{240}$</td>
<td>▼</td>
<td>Potential for production response or feeding of higher-forage diets</td>
</tr>
<tr>
<td>NDFD$_{30}$</td>
<td>▲</td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>▲</td>
<td>▲ Energy Density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for production response or feeding less corn grain</td>
</tr>
</tbody>
</table>
Corn Silage Starch (or NDF) %

- Hybrid impacts grain yield potential, possibly grain:stover ratio, & thus the potential starch %
- But actual starch % largely uncontrolled since varies depending on:
  - Crop growing conditions (i.e. rainfall amounts & timing)
  - Harvest timing relative to kernel maturity
  - Cutting height
- Survey of 4 commercial labs; over 300k samples
  - Normal range was 25% to 39%
Corn Silage NDFD

• Reduced lignin & corresponding greater ivNDFD, DMI & milk yield have consistently been reported for bm₃-type corn silage hybrids in research trials

• 15-year data summary from UW-Madison Agronomy Dept. hybrid performance trials
  ▪ bm₃ ivNDFD 6%- to 11%-units greater than trial averages
  ▪ Milk per ton consistently greater than trial averages
  ▪ Starch % & DM yield per acre trended lower for the bm₃ hybrids included in those trials

• For conventional-type hybrids, progress in improving ivNDFD has been slow & small relative differences among hybrids often observed
Scanning electron microscopy of starch granules in corn: A) starch granules heavily imbedded in prolamin-protein matrix, B) starch granules in opaque corn endosperm with less extensive encapsulation by prolamin-proteins (Gibbon et. al., 2003).

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Hybrid selection for kernel endosperm properties to improve
StarchD very slow to evolve

Genetic effects on StarchD tempered in corn silage
- Harvest should be completed pre-blacklayer
- Kernel processed during harvest
- Prolonged silo storage increases StarchD

No standardized agreed upon method for assessing differences in
StarchD among samples

When altering kernel endosperm properties in WPCS cannot ignore
potential for negative changes in Starch (NDF) %, ivNDFD or
agronomics
Corn Silage Harvesting

- **Conventional Processors**
  - 17-22 mm TLOC
  - ≈20% Roll speed differential
  - 1-2 mm Roll Gap

- **Contemporary Processors**
  - 17-26 mm TLOC
  - 40-50% Roll speed differential
  - 1-3 mm Roll Gap
  - Alternative processor type
    - Cross-grooved rolls
    - Intermeshing discs
Corn Silage Harvesting

- On-the-go TLOC & inoculant rate adjustments to SPFH using on-board NIRS DM measurements
- Earlage/Snaplage heads on SPFH
Corn Silage Microbial Inoculants

- Back-end feedout stability focus versus front-end pH drop focus
- Lactobacillus buchneri use to increase acetate relative to lactate
- Use of L. plantarum/L. Buchneri combo products
- Experimental interest in potential effects on ivNDFD & StarchD
Some thoughts on tomorrow's corn silage?
Will continued grain yield increases cease being our friend?
i.e. we are already seeing 30% NDF, 40% starch sample analyses on corn silage from dairy farms
Corn Silage Hybrid Considerations

• Stover Yield to balance Grain Yields

• Earlage quality

• Replacement Heifers & Dry Cows
  • Low Grain, Starch Contents

• Output trait focus?
  • NDFD; StarchD;
  • Linoleic Acid; Amino Acids
• Brown midrib mutation
  - 1st discovered in 1924 at UMN
  - 4 mutants identified; bm1 (1931) - bm4 (1947)
  - Some agronomic & yield drag constraints inherent to mutants remain

• Low-Ferulate corn mutant
  - Published on recently by Hans Jung’s group at USDA/UMN
  - Similar lignin % but altered lignin chemistry

• Transgenics or CRISPR?
Corn Silage StarchD

• Genetic or transgenic modifications studied

  ▪ Comparisons of Flint, Dent, Reduced-Vitreousness Dent, Floury, Opaque, Waxy Endosperm in Conventional Hybrids (numerous citations but few feeding trials)

  ▪ Floury-Leafy Hybrid (Ferraretto et al., 2015, JDS; Morrison et al., 2014, JDS abstr)

  ▪ Floury-BMR Hybrid (Morrison et al., 2016 JDS abstr)

  ▪ α-Amylase expressed in kernel (Hu et al., 2010, JDS; trials in progress)
<table>
<thead>
<tr>
<th></th>
<th>$CCS^{1}$Starch (TMF2R447)</th>
<th>bm$_3^{1}$ (F2F498)</th>
<th>EXP bm$_3^{1}$ (FBDAS3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lb/d</td>
<td>59$^b$</td>
<td>62$^a$</td>
<td>61$^{ab}$</td>
</tr>
<tr>
<td>Milk, lb/d</td>
<td>96$^b$</td>
<td>104$^a$</td>
<td>106$^a$</td>
</tr>
<tr>
<td>Fat, %</td>
<td>4.00$^a$</td>
<td>3.85$^b$</td>
<td>3.87$^b$</td>
</tr>
<tr>
<td>ECM, lb/d</td>
<td>104$^b$</td>
<td>111$^a$</td>
<td>114$^a$</td>
</tr>
<tr>
<td>ECM/DMI</td>
<td>1.76$^b$</td>
<td>1.79$^b$</td>
<td>1.87$^a$</td>
</tr>
<tr>
<td>MNE, %</td>
<td>35$^c$</td>
<td>38$^b$</td>
<td>40$^a$</td>
</tr>
<tr>
<td>Total Tract Digestibility, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OM</td>
<td>74</td>
<td>75</td>
<td>74</td>
</tr>
<tr>
<td>NDF</td>
<td>58</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>Starch</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

$^1$Fed in TMR containing 49% corn silage and 6% haycrop silage (DM basis) in 5x replicated 3 × 3 Latin Square design with 28d periods
High-Amylase Corn Hybrids

- Syngenta
  - Enogen Feed Corn (EFC)
- GMO
  - Greater kernel amylase as kernel matures
- Developed for ethanol industry
  - Conversion of starch to sugars prior to yeast fermentation
- Recent approval for feeding to livestock
- Animal performance benefits?; WPCS Yield drag?; Seed/Trait Costs?
Corn Silage Harvesting

- TLOC & KPS
  - Fiber Shredding?
  - KPS by image analysis (Luck’s app)
- Earlage/Snaplage
- Toplage/Stalklage?
- Use of on-board NIRS & GPS to better manage harvest for more consistent quality
Corn Silage Microbial Inoculants

- Nutrient digestibility focus
- Mold/Yeast inhibition
Corn Silage

Feeding Considerations

• Supplementing higher corn silage diets
  ▪ peNDF
  ▪ Soluble Fiber
  ▪ Rumen buffering
  ▪ Protein/Amino Acids

• Feeding all reduced lignin, high NDFD forages

• Better incorporation of digestion kinetics into forage evaluation & development of feeding programs
Questions?