Utilization of silages in the diets of high producing dairy cows: Limitations and opportunities

Kenneth F. Kalscheur, USDA-ARS
Peter H. Robinson, University of California – Davis
Ronald D. Hatfield, USDA-ARS

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Outline

1. Forage utilization in the U.S.
2. Formulation of silages into lactating dairy cow diets
3. Limitations and Opportunities
1. Forage utilization in the U.S.
Forage utilization in the U.S.

- Choice of forages for silage in the dairy ration vary depending on climate, soil types and growing conditions of that region.

- What types of forages for silages are commonly used in the U.S.?
Forage utilization in the U.S.

Martin et al. 2017
Forage utilization in the U.S.

Martin et al. 2017
Forage utilization in the U.S.

- In much of the U.S., corn silage is the dominant silage used in dairy cow rations. And it’s growing. Why?
Forage utilization in the U.S.

• In much of the U.S., corn silage is the dominant silage used in dairy cow rations. And it’s growing. Why?
  • Higher energy forage
  • Higher biomass yield
  • Management – less harvesting time and labor, more consistent quality
Forage utilization in the U.S.

- 2\textsuperscript{nd} most popular
  - Alfalfa silage
- Dry climates of southwest U.S.
  - Forage sorghum silage
- Additional silage crops
  - Grass silages
  - Annual grain silages
2. Formulation of silages into lactating dairy cow diets
Importance of silages in diets

- Silages are critical for providing necessary fiber for dairy cow diets
  - Provides energy
  - Regulates the intake of feed
  - Stimulates chewing, saliva production, and rumination
  - Increases buffering of the rumen
  - Regulates rumen function
  - Provides a source of precursors for milk fat
Importance of silages in diets

• NRC (2001) recommendations
  • NDF >25% of the diet DM in lactating dairy cow diets.
  • Forage NDF should be 19% of the diet DM or greater.
1. There is a need to increase animal productivity to meet the increasing demand for animal-sourced food.

2. Increase utilization of feeds that are not in direct competition with human food, monogastric feed, and biofuel feedstock.

3. Lower the cost of the diet.
## Nutrient composition of alfalfa and corn silage

<table>
<thead>
<tr>
<th>Nutrient (% of DM)</th>
<th>Alfalfa</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (% as is)</td>
<td>40.3 ± 12.0</td>
<td>33.7 ± 9.15</td>
</tr>
<tr>
<td>CP</td>
<td>21.6 ± 2.99</td>
<td>8.3 ± 1.06</td>
</tr>
<tr>
<td>NDF</td>
<td>44.1 ± 5.76</td>
<td>43.6 ± 5.91</td>
</tr>
<tr>
<td>ADF</td>
<td>34.4 ± 4.24</td>
<td>25.7 ± 4.04</td>
</tr>
<tr>
<td>Lignin</td>
<td>7.71 ± 3.71</td>
<td>3.25 ± 0.68</td>
</tr>
<tr>
<td>Starch</td>
<td>2.05 ± 1.26</td>
<td>31.8 ± 7.41</td>
</tr>
<tr>
<td>WSC</td>
<td>6.10 ± 4.79</td>
<td>3.24 ± 1.56</td>
</tr>
<tr>
<td>Crude fat</td>
<td>3.81 ± 0.74</td>
<td>3.29 ± 0.48</td>
</tr>
<tr>
<td>Ash</td>
<td>11.1 ± 2.09</td>
<td>4.30 ± 1.22</td>
</tr>
</tbody>
</table>

Dairy One Interactive Feed Composition Libraries (2018)
Schuler et al. (2013)
- Evaluated the optimum dietary forage concentration when using canola meal as a primary protein source.
- Forage was increased from 42% to 66% of the diet.
### Ingredient composition

<table>
<thead>
<tr>
<th>Ingredient (% of DM)</th>
<th>42F</th>
<th>50F</th>
<th>58F</th>
<th>66F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa haylage</td>
<td>12.6</td>
<td>15.0</td>
<td>17.4</td>
<td>19.8</td>
</tr>
<tr>
<td>Corn silage</td>
<td>29.4</td>
<td>35.0</td>
<td>40.6</td>
<td>46.2</td>
</tr>
<tr>
<td>Canola meal</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Ground corn</td>
<td>17.7</td>
<td>16.7</td>
<td>15.7</td>
<td>14.6</td>
</tr>
<tr>
<td>Beet pulp</td>
<td>3.43</td>
<td>2.30</td>
<td>1.10</td>
<td>0</td>
</tr>
<tr>
<td>Corn gluten feed</td>
<td>10.30</td>
<td>6.90</td>
<td>3.40</td>
<td>0</td>
</tr>
<tr>
<td>Soy plus</td>
<td>2.00</td>
<td>2.70</td>
<td>3.50</td>
<td>4.20</td>
</tr>
<tr>
<td>Soybean hulls</td>
<td>9.30</td>
<td>6.20</td>
<td>3.10</td>
<td>0</td>
</tr>
<tr>
<td>Rumen inert fat</td>
<td>2.30</td>
<td>2.30</td>
<td>2.30</td>
<td>2.30</td>
</tr>
<tr>
<td>Vit/Min</td>
<td>1.97</td>
<td>1.97</td>
<td>1.97</td>
<td>1.97</td>
</tr>
</tbody>
</table>
## Production responses

<table>
<thead>
<tr>
<th>Item</th>
<th>42F</th>
<th>50F</th>
<th>58F</th>
<th>66F</th>
<th>SEM</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg</td>
<td>28.0</td>
<td>27.0</td>
<td>25.8</td>
<td>24.8</td>
<td>0.69</td>
<td>L</td>
</tr>
<tr>
<td>Milk, kg</td>
<td>40.1</td>
<td>40.4</td>
<td>40.8</td>
<td>39.1</td>
<td>1.12</td>
<td>NS</td>
</tr>
<tr>
<td>ECM, kg/d</td>
<td>38.0</td>
<td>38.4</td>
<td>39.5</td>
<td>38.7</td>
<td>1.23</td>
<td>NS</td>
</tr>
<tr>
<td>FE (ECM/DMI)</td>
<td>1.36</td>
<td>1.44</td>
<td>1.54</td>
<td>1.57</td>
<td>0.047</td>
<td>L</td>
</tr>
</tbody>
</table>

\(^a\) L=Linear response \((P<0.05)\).

Schuler et al., 2013
3. Limitations and Opportunities
3. Limitations and Opportunities: Protein
Limitation:

Proteolysis of true protein during the ensiling process and its high rumen degradability limit the addition of alfalfa silages in the diet of lactating dairy cows.
Protein

• Challenge with alfalfa silage
  • High buffering capacity of alfalfa slows the decrease in pH during ensiling resulting in greater proteolysis.
  • Sanchez-Duarte and Garcia (2017) showed a linear DMI response to increasing ammonia-N concentration in alfalfa silage (P < 0.001).

\[ DMI = 24.551 - 0.422 \times \text{ammonia-N} \]
• 2\textsuperscript{nd} Challenge with alfalfa silage
  • High in rumen degradable protein (RDP)
  • High inclusion of alfalfa silage result in excessive concentrations of RDP.
  • Excessive protein will be lost as urinary nitrogen and will not be utilized efficiently for milk production (Jonker et al., 1998).
• Decreasing proteolysis during ensiling or decreasing overall degradability of the protein would result in greater value of the alfalfa silage formulated in lactating dairy cow diets.

• **Long term research solutions:**
  • Increase the activity of polyphenol oxidase to reduce proteolysis in silages (Lee et al. 2006; Sullivan and Hatfield, 2006).
  • Increase the concentration of condensed tannins to reduce RDP from alfalfa silage (Potkański et al., 2002; Coblentz and Grabber, 2013).
3. Limitations and Opportunities: Fiber
• Limitation:
  • High fiber concentration or poor digestibility of fiber limits intake of high producing dairy cow resulting in less than desirable milk production.
Methods to improve NDF digestibility to increase silage utilization in dairy cow diets

- **Physical treatments**
  - Chopping, shredding, grinding, pelleting, steaming

- **Biological treatments**
  - Enzymes, inoculants, yeast, fungi

- **Chemical treatments**
  - Acids, hydrolyzing alkalis

- **Genetic technologies**
  - Variety selections available to producers
Corn silage
Brown mid-rib (BMR) varieties

- BMR mutation reduces lignin concentration
- Characteristic brown mid-rib color on the leaf
- Improvement in digestibility outweighs negative agronomic characteristics (lower yield, potential for lodging, more stressed by drought, and more susceptible to northern corn leaf blight).
Advantages of BMR corn silage

• Lower in lignin content, higher in fiber digestibility, results in greater DMI (Holt et al., 2013).

• Miner Institute has reported that cows fed BMR corn silage (Thomas, 2018):
  • Consumed more feed, but ruminated 20-25 minutes less per lb of NDF consumed.
  • Spent 5-10 minutes less time eating per pound of NDF consumed.
  • Spent up to 30 minutes/day less time at the feed bunk.
### Meta-analysis of 48 studies

<table>
<thead>
<tr>
<th>Item</th>
<th>CONV</th>
<th>BMR</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg/d</td>
<td>24.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.4</td>
<td>0.001</td>
</tr>
<tr>
<td>Milk, kg/d</td>
<td>37.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Fat, %</td>
<td>3.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>Protein, %</td>
<td>3.06</td>
<td>3.07</td>
<td>0.03</td>
<td>0.42</td>
</tr>
<tr>
<td>MUN, mg/dL</td>
<td>15.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.6</td>
<td>0.02</td>
</tr>
<tr>
<td>NDFD, % of NDF</td>
<td>42.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Ferraretto and Shaver (2015)
Low-lignin alfalfa
Low-lignin alfalfa

HiGest™ 360 - developed by Alforex Seeds
- 7-10% reduction in lignin

HarvXtra™ - Developed by Forage Genetics International
- 10-15% reduction in lignin
Value of low-lignin alfalfa varieties

- Wider harvest window?
- Later harvest
  - Greater tonnage per cutting
  - Make use of full growing season
  - Reduce number of cuttings
    - a 15 to 18% lignin reduction means we could harvest 8 to 10 days later
- Improved forage quality
Yield and quality curve of alfalfa

Yield

Forage Quality

Optimal yield and quality

Percent of Maximum Yield or quality

Days of Regrowth

Courtesy of Dr. Dave Combs
Yield and quality curve of alfalfa

- **Yield Curve of Alfalfa**: The graph illustrates the yield of alfalfa over the days of regrowth. The yield is measured as a percentage of the maximum yield.

- **Quality Curves**: Two curves are shown:
  - **Low-Lignin Alfalfa Quality**: This curve shows a steady decline in yield but a progressive improvement in quality.
  - **Conventional Alfalfa Quality**: This curve also shows a steady decline in yield but a lesser improvement in quality compared to the low-lignin variety.

The graph is courtesy of Dr. Dave Combs.
Low-lignin alfalfa plot studies

  - University of Minnesota. 4 locations over 2 years.
  - Reduced lignin alfalfa (HarvXtra) averaged 8% less acid detergent lignin and 10% greater NDFD compared to 3 other varieties.
  - Delaying reduced lignin alfalfa harvest increased forage mass and maintained quality.

- Sulc et al. (2016)
  - Six states (KS, MI, OH, PA, CA, WI).
  - Three varieties (HarvXtra) vs. 2 other varieties.
Lignin

18% lower in lignin

Sulc et al. (2016)
10% higher in NDF digestibility

Sulc et al. (2016)
Low-lignin alfalfa plot studies

• Donnelly et al. (2018).
  • University of Wisconsin. 4 alfalfas: two control varieties, HarvXtra, and HiGest.
  • Fields were sampled twice per week from May 4th to June 19th.
Low-lignin alfalfa plot study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Alfalfa variety</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1</td>
<td>C2</td>
<td>HX</td>
<td>HG</td>
<td>SEM</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>L:S ratio, DM</td>
<td>0.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.59&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Stem composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADL, % DM</td>
<td>7.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.74&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.42&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.08</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>NDF, % DM</td>
<td>46.0</td>
<td>48.4</td>
<td>45.7</td>
<td>45.8</td>
<td>0.8</td>
<td>0.06</td>
</tr>
<tr>
<td>iNDF, % NDF</td>
<td>45.6&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>48.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.6</td>
<td>&lt; 0.04</td>
</tr>
<tr>
<td>TTNDFD, % NDF</td>
<td>39.5&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>37.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>43.5&lt;sup&gt;a†&lt;/sup&gt;</td>
<td>41.5&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.6</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Kd, %/h</td>
<td>5.98&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.13&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>7.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.4</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

<sup>a,b,c</sup> Means within a row with different superscripts differ (P < 0.05).

<sup>†</sup>The HX and HG varieties differed (P < 0.10), C1 and C2 differed from each other (P < 0.10).

Donnelly et al. (2018)
Feeding low-lignin alfalfa

• Weakley et al. (2008)
  • NDFD was improved 42.5 vs 53.5% for control vs. low-lignin alfalfa ($P < 0.05$).
  • Milk yield was improved 27.2 vs 38.4 kg/d for control vs. low-lignin alfalfa ($P < 0.05$).

• Additional feeding studies will be needed to investigate how low-lignin alfalfa silages can best be formulated in lactating dairy cow diets.
Feeding low-lignin alfalfa silage with BMR corn silage

• Interest by commercial dairies to combine both of these varieties to continue to increase silages in diets.

• No research data to date.
3. Limitations and Opportunities: Energy
• **Limitation:**
  
  • Meeting the energy requirements for high producing dairy cows continues to be a major limitation for cows on high silage diets.
  
  • Need to find higher energy forages that can be ensiled which can replace concentrate feeds.
Corn silage

• Corn silage will continue to be a major ingredient in high producing dairy cow diets.
Opportunities - energy

Feedstuffs

NUTRITION & HEALTH

Key step forward for game-changing grass

New Zealand researchers developing ryegrass that may boost animal growth and cut methane emissions.

Jul 12, 2018
Conclusions

- With the goal to increase silage utilization in the dairy cow diets:
  - Protein utilization
  - Fiber utilization
  - Energy availability

- Opportunities are on the horizon to improve the utilization of these nutrients leading to greater inclusion of silages in the diets of high producing dairy cows.
QUESTIONS?

Leading the world in integrated dairy forage systems research.

U.S. Dairy Forage Research Center

www.ars.usda.gov/mwa/madison/dfrc