Alfalfa: Hay, Haylage, Baleage and Other Novel Products

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Research Lab, Madison, WI
Research Farm, Prairie du Sac, WI
Alfalfa: Hay, Haylage, Baleage, and Other Novel Products

- Introduction
- Alfalfa utilization by dairy cattle
  - Alfalfa vs corn silage in diets
  - Protein utilization of alfalfa
- Composition of alfalfa hay and corn silage
- Novel alfalfa products
2003 U S Alfalfa Hay Production

- 76.3 million tons
- $6.9 billion
- 4th following corn, soybeans and wheat
- Idaho ranks 2nd behind CA in value
Leading Alfalfa Hay Production States, 1,000 tons, 2003

- **Top 10 States**
  - 58 % of U. S.
  - 60 % of Acre
  - 4 states NC
  - 6 states West
  - 5 Lead Dairy

![Bar chart showing leading alfalfa hay production states in 2003](chart.png)
Leading Alfalfa Hay Acreage States, 1,000 acres, 2003

- Top 10 States
  - 58% of U. S.
  - 63% of Acre
  - 3 states NC
  - 7 states West
  - 4 Lead Dairy
Leading Alfalfa Forage Production States, 1,000 tons, 2003

- Top 10 States
  - 59% of U. S.
  - 59% of Acre
  - 4 states NC
  - 1 state NE
  - 5 states West
  - 6 Lead Dairy
Percent of Total 2003 Alfalfa Production - Haylage
California Dairy Nutritionists
Value Alfalfa Hay

- High energy value
- Its rapid ruminally digested structural fiber which stimulates intake
- Coarse structural fiber that stimulates chewing and salivation which results in rumen buffering and buffering capacity
- High protein
- Relatively high proportion of protein that escapes rumen undegraded

Peter Robinson, University of Davis - CA
## Alfalfa: Corn Silage

50% forage: 50% concentrate

<table>
<thead>
<tr>
<th>Item</th>
<th>AS¹</th>
<th>2/3 AS</th>
<th>1/3 AS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Milk production</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature cows, lb/hd/305</td>
<td>21,148</td>
<td>22,422</td>
<td>22,100</td>
</tr>
<tr>
<td>1st calf cows, lb/hd/305</td>
<td>17,911</td>
<td>18,546</td>
<td>18,008</td>
</tr>
<tr>
<td>3.5 % FCM, lb/d</td>
<td>68.2</td>
<td>72.4</td>
<td>70.0</td>
</tr>
<tr>
<td>Milk protein, lb/d</td>
<td>2.09</td>
<td>2.22</td>
<td>2.18</td>
</tr>
</tbody>
</table>

¹ (AS) Alfalfa silage: % DM, 40.2; CP, 19.5; ADF, 33.9; and NDF, 40.1. (CS) corn silage: % DM, 35.5; CP, 7.8; ADF, 25.3; and NDF, 45.3

## High Alfalfa Haylage Diet

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Protein</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM intake, lb</td>
<td>48.4(^b)</td>
<td>55.9(^a)</td>
<td>49.5(^b)</td>
</tr>
<tr>
<td>BW gain, lb</td>
<td>50.6</td>
<td>48.4</td>
<td>33.0</td>
</tr>
<tr>
<td>3.5 % FCM, lb</td>
<td>63.4(^c)</td>
<td>75.0(^a)</td>
<td>67.5(^{bc})</td>
</tr>
<tr>
<td>Milk protein, lb</td>
<td>1.89(^b)</td>
<td>2.29(^a)</td>
<td>1.94(^b)</td>
</tr>
</tbody>
</table>

\(^{abc}\) Means in same row with different superscripts differ (p<0.01)

**SOURCE:** Dhiman and Satter, 1993.
## Protein Use of Alfalfa

<table>
<thead>
<tr>
<th>Item</th>
<th>silage</th>
<th>hay</th>
<th>silage +FM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>hay+FM&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP,% of DM</td>
<td>17.1</td>
<td>15.4</td>
<td>18.6</td>
<td>17.0</td>
</tr>
<tr>
<td>DM intake</td>
<td>49.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>52.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>BW change</td>
<td>-0.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.99&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.08&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk</td>
<td>77.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>79.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>82.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>81.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat</td>
<td>2.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.60&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.69&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Protein</td>
<td>2.29&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.49&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SNF</td>
<td>6.64&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>abc</sup> Means in same row with different superscripts differ (p<0.05)

<sup>1</sup> Diets supplemented with 3 % (DM basis) low-soluble fish meal.

**SOURCE:** Broderick, 1995.
Feed Storage Problems

• However in alfalfa, our primary forage:
Supplementation of a 50% Alfalfa Silage Diet with Raw or Roasted Soybeans (Faldet & Satter, 1991)

Milk Production (lb/day)

Week of Lactation
# Effect of Silage Preservation on Alfalfa

<table>
<thead>
<tr>
<th>Item</th>
<th>Control C³</th>
<th>Formic acid F⁴</th>
<th>Grainmax G⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture, %</td>
<td>61.7</td>
<td>64.8</td>
<td>64.1</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>21.4</td>
<td>20.8</td>
<td>21.1</td>
</tr>
<tr>
<td>NPN, % of N</td>
<td>43.1</td>
<td>29.1</td>
<td>35.5</td>
</tr>
<tr>
<td>NDF, %</td>
<td>38.9</td>
<td>41.2</td>
<td>41.3</td>
</tr>
</tbody>
</table>

³Control silage was ensiled untreated

⁴Silage ensiled after treatment of 2 gal/T of 90 % formic acid

⁵Silage ensiled after treatment with 1.5 gal/T of Grainmax & 16% formaldehyde.

Broderick and Satter. 1998. Proc. 4-State DFFMC
## Effect of Silage Preservation on Alfalfa

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Formic acid F</th>
<th>Grainmax G</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C(^3)</td>
<td>F(^4)</td>
<td>G(^5)</td>
</tr>
<tr>
<td>Intake and milk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM intake, lb/day</td>
<td>40.3</td>
<td>40.1</td>
<td>43.4</td>
</tr>
<tr>
<td>Milk, lb/day</td>
<td>(64.4^b)</td>
<td>(71.1^a)</td>
<td>(71.4^a)</td>
</tr>
<tr>
<td>Fat, lb/day</td>
<td>(2.4^b)</td>
<td>(2.9^a)</td>
<td>(2.9^a)</td>
</tr>
<tr>
<td>Protein, lb/day</td>
<td>(1.8^b)</td>
<td>(2.0^a)</td>
<td>(1.9^ab)</td>
</tr>
</tbody>
</table>

\(^3\)Control silage was ensiled untreated

\(^4\)Silage ensiled after treatment of 2 gal/T of 90 % formic acid

\(^5\)Silage ensiled after treatment with 1.5 gal/T of Grainmax & 16% formaldehyde.

Broderick and Satter. 1998. Proc. 4-State DFFMC
Post Harvest Proteolysis in Alfalfa
Impact on dairy production

- Increased NPN decreases the efficiency of protein utilization in ruminants.

  - Inefficient utilization of alfalfa protein requires the feeding of supplemental protein with high RUP to maximize milk production.
  - Inefficient utilization of alfalfa protein also results in the excretion of excess rumen NH₃, leading to increased N losses to the environment.

Typical NPN content of silage
Alfalfa can be used as a model to study the inhibition of protein breakdown in silages. 

PPO = Polyphenol Oxidase gene from red clover
Improving Alfalfa for Dairy Rations

- Currently using harvesting management to improve alfalfa quality
  - Immature alfalfa has many appealing nutritional properties
    - Low in fiber
      - High digestibility
      - High intake potential
    - Rapid rate of digestion
    - High in crude protein
# Impact of Harvest Management on Forage Quality

<table>
<thead>
<tr>
<th>Description</th>
<th>CP</th>
<th>EE</th>
<th>Ash</th>
<th>Starch</th>
<th>Pectin</th>
<th>aNDF</th>
<th>ADF</th>
<th>ADL</th>
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</thead>
<tbody>
<tr>
<td><strong>ALFALFA HAY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exceptional</td>
<td>25.4</td>
<td>2.7</td>
<td>10.4</td>
<td>3.1</td>
<td>14.2</td>
<td>30.0</td>
<td>24.0</td>
<td>4.53</td>
</tr>
<tr>
<td>Very high</td>
<td>24.0</td>
<td>2.6</td>
<td>9.9</td>
<td>2.9</td>
<td>13.2</td>
<td>34.1</td>
<td>27.0</td>
<td>5.38</td>
</tr>
<tr>
<td>High quality</td>
<td>22.5</td>
<td>2.5</td>
<td>9.5</td>
<td>2.7</td>
<td>12.3</td>
<td>38.2</td>
<td>30.0</td>
<td>6.23</td>
</tr>
<tr>
<td>Good quality</td>
<td>21.0</td>
<td>2.4</td>
<td>9.1</td>
<td>2.5</td>
<td>11.4</td>
<td>42.2</td>
<td>33.0</td>
<td>7.08</td>
</tr>
<tr>
<td>Fair quality</td>
<td>19.5</td>
<td>2.2</td>
<td>8.7</td>
<td>2.3</td>
<td>10.5</td>
<td>46.3</td>
<td>36.0</td>
<td>7.93</td>
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<tr>
<td><strong>CORN SILAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V. high grain</td>
<td>8.3</td>
<td>3.2</td>
<td>4.1</td>
<td>31.1</td>
<td>1.7</td>
<td>36.0</td>
<td>21.0</td>
<td>1.57</td>
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<tr>
<td>High grain</td>
<td>8.6</td>
<td>3.1</td>
<td>4.6</td>
<td>27.2</td>
<td>1.6</td>
<td>40.5</td>
<td>24.0</td>
<td>1.91</td>
</tr>
<tr>
<td>Normal</td>
<td>8.8</td>
<td>3.0</td>
<td>5.1</td>
<td>23.2</td>
<td>1.5</td>
<td>45.0</td>
<td>27.0</td>
<td>2.25</td>
</tr>
<tr>
<td>Low grain</td>
<td>9.0</td>
<td>2.8</td>
<td>5.7</td>
<td>19.2</td>
<td>1.4</td>
<td>49.5</td>
<td>30.0</td>
<td>2.59</td>
</tr>
<tr>
<td>Very low grain</td>
<td>9.3</td>
<td>2.7</td>
<td>6.2</td>
<td>15.3</td>
<td>1.3</td>
<td>54.0</td>
<td>33.0</td>
<td>2.93</td>
</tr>
</tbody>
</table>
## Ideal Alfalfa – Sole Diet

<table>
<thead>
<tr>
<th>Insoluble CHO and Lignin</th>
<th>Cow Req.</th>
<th>Corn Silage</th>
<th>Alfalfa Silage</th>
<th>Hi-Qual Alfalfa</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF</td>
<td>28</td>
<td>43</td>
<td>43</td>
<td>28</td>
</tr>
<tr>
<td>ADF</td>
<td>19</td>
<td>24</td>
<td>33</td>
<td>19</td>
</tr>
<tr>
<td>AD Lignin</td>
<td>3.0</td>
<td>8.6</td>
<td>4.0</td>
<td></td>
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<tr>
<td>NDF digestion rate</td>
<td>.06</td>
<td>.10</td>
<td>.15</td>
<td></td>
</tr>
<tr>
<td>Physically effective NDF</td>
<td>22</td>
<td>38.7</td>
<td>40.8</td>
<td>25.2</td>
</tr>
</tbody>
</table>
### Ideal Alfalfa – Sole Diet

<table>
<thead>
<tr>
<th>Nonstructural Components</th>
<th>Cow Req.</th>
<th>Corn Silage</th>
<th>Alfalfa Silage</th>
<th>Hi-Qual Alfalfa</th>
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<tbody>
<tr>
<td>Soluble CHO</td>
<td>45</td>
<td>42.0</td>
<td>25.0</td>
<td>28.0</td>
</tr>
<tr>
<td>Nonfibrous CHO</td>
<td>40</td>
<td>10</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Starches</td>
<td>30</td>
<td>36</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Pectins+</td>
<td>2</td>
<td>15</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hi-Qual Alfalfa</td>
<td></td>
<td></td>
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</tbody>
</table>
# Apparent Dry Matter Digestibility of AH and CS

<table>
<thead>
<tr>
<th>Item</th>
<th>AH 24%ADF</th>
<th>AH 27%ADF</th>
<th>CS proc 24%ADF</th>
<th>CS proc 27%ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td>% aNDF</td>
<td>30.0</td>
<td>34.1</td>
<td>40.5</td>
<td>45.0</td>
</tr>
<tr>
<td>% NDFD</td>
<td>52.1</td>
<td>46.8</td>
<td>61.4</td>
<td>60.6</td>
</tr>
<tr>
<td>% dNDF</td>
<td>15.6</td>
<td>16.0</td>
<td>24.9</td>
<td>27.3</td>
</tr>
<tr>
<td>% NDS</td>
<td>70.0</td>
<td>65.9</td>
<td>59.5</td>
<td>55.0</td>
</tr>
<tr>
<td>% dNDS</td>
<td>68.6</td>
<td>64.6</td>
<td>58.3</td>
<td>53.9</td>
</tr>
<tr>
<td>% True DM digestibility</td>
<td>84.2</td>
<td>80.6</td>
<td>83.2</td>
<td>81.2</td>
</tr>
<tr>
<td>% Endo fecal DM excr</td>
<td>-12.9</td>
<td>-12.9</td>
<td>-12.9</td>
<td>-12.9</td>
</tr>
<tr>
<td>% Apparent DMD</td>
<td>71.3</td>
<td>67.7</td>
<td>70.3</td>
<td>68.3</td>
</tr>
</tbody>
</table>

**SOURCE:** Mertens, 2003.
Forage Fiber Digestibility

Orchardgrass

- Leaf
- Stem

Alfalfa

- Leaf
- Stem

Vegetative

Flowering

Seed

NDF Digestibility (%)
New Alfalfa Products of high value are needed to expand acreage...

Research efforts underway to:
- Develop alfalfa with value-added traits
- Develop new processing technologies
Three methods of forage fractionation exist:

- Wet fractionation; separation into a juice and a fiber fraction
- Dry fractionation; separation into leaves and stems
- Animal fractionation; passage of whole plant through digestive systems of ruminant animals, leaving a high fiber residue.
Novel Products of Alfalfa

Two important conditions must be met for alfalfa fractionation to be feasible and sustainable:

- Total value of resulting products must be greater than the original forage plus the cost of processing;
- All fractions must have economic value to avoid creating a waste stream.
Novel Products of Alfalfa

- Wet-fractionation process has two advantages for agriculture:
  - Forage crops can be harvested almost independent of weather, since moisture is removed mechanically rather than by mother nature.
  - A versatile protein concentrate is obtained which can be fed to non-ruminants, including humans, as well as dairy cattle.
**FRACTIONATION METHODS**

1. **Wet**
   - **Herbage**
     - **Juice**
       - **Enzymes (Transgenic)**
     - **“Fiber”**

2. **Dry**
   - **Herbage**
     - **Leaves**
       - **Enzymes (Transgenic)**
     - **Stems**

3. **Animal**
   - **Herbage**
     - **“Digestibles” (to animal)**
     - **Fibrous Fraction**
       - **Hardwood**
       - **“Masonite”**
       - **Biofilters**
       - **Bio plywood**
Development of Green Genes

Transgenic Phytase-rich Alfalfa

- Phytase enzyme makes P in grain ration of monogastric diets more available (poultry, swine, and fish)
- Less P excreted in feces
- Phytase enzyme levels of 1 - 2 % of soluble protein possible
- Phytase extraction with wet fractionation gives added value of xanthophyll & high protein
- Phytase is stable - alfalfa leaf meal
Alfalfa - Produced Phytase in Poultry Rations:

- Eliminates need for phosphorus supplementation
- Reduces the phosphorus content of feces to less than half
VALUE OF PHYTASE-PROTEIN-PIGMENT CONCENTRATE PER ACRE-YEAR

- **PHYTASE**: 4lb @ $150/lb = $600
- **XANTHOPHYLL**: 1.2lb @ $175/lb = $245
- **PROTEIN CONC.**: 1375lb x $0.10/lb = $137

Total: $982
Potential new uses of alfalfa

- Electric generation
Minnesota Agri-Power:
Project to Produce Electricity and Livestock Feed (and Improve the Environment) with Alfalfa

- Separate alfalfa hay into leaf and stem fractions.
- Produce electricity from the low-value stems.
- Utilize the leaves as a feed supplement for livestock.
## Composition of Leaf Meal - Fractionation

<table>
<thead>
<tr>
<th>Component</th>
<th>Separation</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lab</td>
<td>‘96</td>
</tr>
<tr>
<td>Crude protein</td>
<td>25.2</td>
<td>21.9</td>
</tr>
<tr>
<td>NDF</td>
<td>36.0</td>
<td>36.5</td>
</tr>
<tr>
<td>ADF</td>
<td>21.5</td>
<td>21.9</td>
</tr>
<tr>
<td>Ash</td>
<td>--</td>
<td>11.3</td>
</tr>
</tbody>
</table>

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Dry Alfalfa

- Leaf Meal
  - Protein Supplement
    - Dairy, Beef, and Poultry
    - 40-50 % of ground hay

- High fiber
  - Combustion, Gasification
  - Or Enzymatic Hydrolysis
  - 50-40 % of ground hay
Bio-degradable plastics made from Lactic Acid
Fiber Board and Filter Mats from Manure

- Thick Filter Mat
- Fiber Board
- Thin Filter Mat
Fresh Alfalfa

**Juice**
- Heat coagulate
- Protein Concentrate
- Poultry supplement or calf-replacer
  - 25 % of original crop dry matter

**High fiber**
- Ruminant feed
  - Store silage in bunkers
  - Process fiber
- New products
  - 75 % of original crop dry matter
Fractionating for Quality

- Alfalfa fractionating at harvest:
Fractionating for Quality

- Alfalfa *fractionating* at harvest:
Fractionating for Quality

Why fractionate alfalfa at harvest:

- Leaf yield and quality relatively unaffected by maturity.
- Stem quality diluted with age.
- Conventional practices co-mingle high- and low-quality.
Fractionating for Quality

Why *fractionate* alfalfa at harvest:

- Fractionated leaves and stems can be target fed more optimally.

- Single day harvesting possible.
  
  • **Leaves**: direct-ensiled with amendment
  
  • **Stems**: wilted and chopped on same day

- Fewer cutting possible
Fractionating for Quality

- Why fractionate alfalfa at harvest:
  - Value-added products possible:
    - Leaves: protein concentrates, pigmenting agents
    - Stems: fiberboard, paper pulp, energy
Fractionating for Quality

What is the big hurdle with alfalfa harvest fractionation:

- Direct ensiling with amendment:
  
  • About 1 ton ground corn grain or DDG needed for every acre
Potential new uses of alfalfa

- Electric generation
- Protein production
Biotechnology Applications in Alfalfa

- Insertion of BT gene to deter insect feeding
- Coat protein for control of viruses
- Improved winterhardiness
- Balanced animal diets
- Alfalfa bioremediation
- Alfalfa root & nodules
- Human proteins
Potential new uses of alfalfa

- Electric generation
- Protein production
- Ethanol production
Biomass Conversion to Ethanol

Grind

Pretreatment to Remove Inhibitors

Enzymatic Breakdown of Polysaccharides

Residual Solids

Sugars

Fermentation

Ethanol Recovery

Electricity & Processing Heat
Alfalfa in Crop Rotations:

- Adds nitrogen via biological fixation
- Improves water infiltration and soil quality
- Reduces soil erosion from wind and water
- Improves yield of subsequent crop
- Reduces N fertilizer demands of subsequent crops
Alfalfa in Crop Rotations:

- Helps protect surface and ground water
- Acts as waste-water recycler
Alfalfa and grass CRP effectively filter tile drain water

>40 million acres are tile drained in the Upper Midwest

Randall, Huggins, Russelle et al., 1997
Risk of groundwater nitrate contamination

Alfalfa is well adapted to grow in these areas.
A multidisciplinary collaboration of public and private scientists

- Dairy Nutrition (USDFRC)
- Biochemistry (Noble Foundation and USDFRC)
- Molecular/cell biology (Noble, FGI and DowAgro)
- Agronomy
- Plant breeding (FGI)
Novel Products of Alfalfa

Summary and Conclusions

- Alfalfa can be processed to provide products of higher value.
- Processing green alfalfa via wet fractionation removes effects of weather on harvest.
- Corn and soybean cash farmers will benefit from all types of fractionation discussed.
- The Alfalfa Industry must cooperate to support research and development to obtain new products from alfalfa.