Agronomic Practices and Forage Quality

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What about Fiber?

33%-55% Cell Wall (NDF-Fiber)
# Hay Quality Guidelines - Alfalfa

## Range of Hay Quality Analysis for Alfalfa Quality Marketing Groups

<table>
<thead>
<tr>
<th>Quality Level</th>
<th>NDF%</th>
<th>NDFD%</th>
<th>CP</th>
<th>ADF%</th>
<th>RFV</th>
<th>TDN (90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supreme</td>
<td>&lt;33</td>
<td>35</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premium</td>
<td>&gt;48</td>
<td>42</td>
<td>38</td>
<td>&gt;22</td>
<td>29</td>
<td>55.9</td>
</tr>
<tr>
<td>Good</td>
<td>&gt;35</td>
<td>42</td>
<td>38</td>
<td>&gt;22</td>
<td>29</td>
<td>54.5</td>
</tr>
<tr>
<td>Fair</td>
<td>&gt;39</td>
<td>42</td>
<td>38</td>
<td>&gt;27</td>
<td>32</td>
<td>52.5</td>
</tr>
</tbody>
</table>

Calculated Values:

- RFV: >180, 150, 125, 100
- TDN (90%): 55.9, 54.5, 52.5, 50.5
**Price of Alfalfa Hay (November 2016)**

(The Hoyt Report)

<table>
<thead>
<tr>
<th>Quality Category</th>
<th>Volume</th>
<th>Price</th>
<th>Volume</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supreme</td>
<td>1700</td>
<td>$240-$253</td>
<td>1600</td>
<td>$230-$250</td>
</tr>
<tr>
<td>Premium</td>
<td>350</td>
<td>$220-$235</td>
<td>2500</td>
<td>$210-$240</td>
</tr>
<tr>
<td>Good</td>
<td>650</td>
<td>$165-$185</td>
<td>475</td>
<td>$160-$180</td>
</tr>
<tr>
<td>Fair</td>
<td>1950</td>
<td>$140-$145</td>
<td>1600</td>
<td>$135-$150</td>
</tr>
<tr>
<td>Difference top-bottom</td>
<td>$103</td>
<td>$98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Probably $250-$300 million per year gained or lost due to quality (California)
What is a nutritionist looking for?

1. Total Digestible Energy (TDN, NEL, Total potential biological energy of forage)
2. Energy per unit time (Intake Potential) (digestibility)
3. Effectively Absorbed Protein (both rumen available and rumen undegradable)
4. Nutritionally Effective Fiber (physical value)
5. Mineral Content (ion balance)
What is the ‘good stuff’ in forages?
What’s in a Forage Plant?

Lipid (1-2%)
Protein (17-25%)
(8-16% grasses)

NDF (35-45%)
(-70% grasses)
Cellulose
Hemicellulose
lignin

Non-Fiber (NS)
Carbohydrates
(25-35%)

Rumen digestible,
Rumen ‘by pass’

Digestible NDF 35-60%

ADF (25-70%)
Cellulose
lignin

Ash (7-14%)

Dry Matter

Water

Carbohydrates
(25-35%)

Digestible NDF 35-60%
To be clear:

- Fiber content is important
- Fiber digestibility may be more important than fiber itself
- How much digestible energy is produced from a kg of forage?
What factors influence forage quality in the field?
Important Factors:

- Whole Plant Level:
  - Leaf – Stem Ratio

- Cellular level (microscopic):
  - Soluble carbohydrates
  - Development of lignin (high fiber)
  - Greater Cell Wall
  - Loss of Carbohydrate
Major mechanisms influencing alfalfa quality in the field:

- Leaf Percentage
- Plant Maturity at Harvest
- Environment (temperature)
- Species Mix (Weeds)
- Harvest Conditioning
Plant Maturity:

- The **single most important factor** influencing alfalfa quality
Relationship between yield and quality

- Total Yield
- Stem Yield
- Forage Digestibility
- Leaf Yield

Time (days):
- Vegetative
- Bud
- First Flower
- Full Flower
- Post-Flower

2017 Forage Quality and Agronomic Practices
D.H. Putnam, UC Davis
Leaf Percentage and TDN

(Whole Plant)

Leaf Percentage (%)

TDN (90%DM)

1999 Data – T. Ackerly, UC Davis

D.H. Putnam, UC Davis
Effect of Plant Maturity on Leaf Percentage:

- Days after 1 March
- Leaf Percent (% of DM)

Graph showing the decrease in leaf percent as days from 1 March increase.
Steve Orloff’s High quality CA hay

Steve Orloff, photo
Plant Maturity: Changes in Quality

- Plant is growing mostly stems as it matures
- Those stems are increasingly poorer in Quality

1999 Data – T. Ackerly, UC Davis

2017 Forage Quality and Agronomic Practices
## Effect of Harvest Maturity on Yield, Quality and Leaf% (cutting schedule)

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Days</th>
<th>Yield</th>
<th>TDN</th>
<th>ADF</th>
<th>CP</th>
<th>Leaf%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Bud</td>
<td>21</td>
<td>7.5</td>
<td>56.3</td>
<td>26.3</td>
<td>29.1</td>
<td>58</td>
</tr>
<tr>
<td>Mid-Bud</td>
<td>25</td>
<td>8.8</td>
<td>54.2</td>
<td>29.5</td>
<td>21.3</td>
<td>56</td>
</tr>
<tr>
<td>10%Bloom</td>
<td>29</td>
<td>9.9</td>
<td>52.4</td>
<td>32.2</td>
<td>21.3</td>
<td>53</td>
</tr>
<tr>
<td>50%Bloom</td>
<td>33</td>
<td>11.4</td>
<td>52.0</td>
<td>32.7</td>
<td>18.0</td>
<td>50</td>
</tr>
<tr>
<td>100%Bloom</td>
<td>37</td>
<td>11.6</td>
<td>50.1</td>
<td>35.5</td>
<td>16.9</td>
<td>47</td>
</tr>
</tbody>
</table>

Data: V. Marble, 1974
## Effect of Harvest Maturity on Weeds and Stand

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Days</th>
<th>Weeds</th>
<th>Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Bud</td>
<td>21</td>
<td>48</td>
<td>29</td>
</tr>
<tr>
<td>Mid-Bud</td>
<td>25</td>
<td>54</td>
<td>38</td>
</tr>
<tr>
<td>10% Bloom</td>
<td>29</td>
<td>8</td>
<td>45</td>
</tr>
<tr>
<td>50% Bloom</td>
<td>33</td>
<td>0</td>
<td>56</td>
</tr>
<tr>
<td>100% Bloom</td>
<td>37</td>
<td>0</td>
<td>50</td>
</tr>
</tbody>
</table>

Data: V. Marble, 1974

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D.H. Putnam, UC Davis
Forage quality effect on milk production at three concentrate levels

From Kawas et al., 1989
Want High Quality?

- So just cut early, right?
The Yield/Quality Tradeoff
(Yolo County)

\[ y = 0.0402x + 1.25 \]
\[ R^2 = 0.6451 \]

\[ y = -0.2262x + 55.442 \]
\[ R^2 = 0.5715 \]
Changes in yield & quality for cut 1 averaged over two years for Yolo County, CA.

CUT 1 Yield - Yolo County, CA

\[ y = 0.0326x + 1.0988 \]

\[ R^2 = 0.7095 \]

CUT 1 ADF - Yolo County, CA

\[ y = 0.2565x + 27.03 \]

\[ R^2 = 0.6477 \]
Daily change in yield for all cuts and locations.

- Yolo Cut 1
- Fresno Cut 1
- Siskiyou Cut 1
- Yolo Cut 2
- Fresno Cut 2
- Siskiyou Cut 2
- Yolo Cut 4
- Fresno Cut 4
- Yolo Cut 6
- Fresno Cut 6

Date:
- Early Spring
- Late Spring
- Summer
- Fall

Lbs/acre/day
Daily changes in ADF for all cuts and locations.

Days Required to Increase ADF 1%

<table>
<thead>
<tr>
<th>Location</th>
<th>Cut 1</th>
<th>Cut 2</th>
<th>Cut 2</th>
<th>Cut 4</th>
<th>Cut 4</th>
<th>Cut 6</th>
<th>Cut 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yolo</td>
<td>4</td>
<td>1.3</td>
<td>3.25</td>
<td>1.75</td>
<td>1.4</td>
<td>2.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Fresno</td>
<td>3</td>
<td>2.5</td>
<td>3</td>
<td>1.4</td>
<td>2.7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Siskiyou</td>
<td>3</td>
<td>3</td>
<td>3.25</td>
<td>1.75</td>
<td>1.4</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

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Yield vs. ADF cut 5

\[ y = 1.1594x + 18.368 \]

\[ R^2 = 0.5972 \]

Yield (t/a) 2000-2001

ADF (%)

High Yield, Low Fiber
High Yield, High Fiber
'SUPREME'
'PREMIUM'
'GOOD'
'FAIR'
CUF 101
Moapa 69

D.H. Putnam, UC Davis
Alfalfa Quality: Always a Dilemma:

Yield

Stand Life

Quality

What about $$$?
Common Hypothetical Return Curve

- **Extremely Early Harvest**: Price premium for very high quality too small to compensate for low yield.
- **'Dairy Quality' Harvest**: High returns at dairy premium price.
- **Just Short of 'Dairy Quality' Harvest**: Just missed 'dairy quality'; yield does not yet compensate for large price drop.
- **Maximum Yield Harvest**: High yield compensates for price of lower quality hay.

Days

Gross Returns ($/A)
Cutting Schedules:

- **THE MAJOR** way to manipulate Quality in Alfalfa & Forages
- Yield/Quality/Stand Tradeoff is a complex management issue for growers.
YIELD AND QUALITY
Davis, CA, Average 2002-2004

% of Yield in each quality category

- Utility
- Fair
- Good
- Premium
- Supreme

Yield (t/a)

Early Mid Late

Cutting Schedule

Yield and Quality

Low Quality

High Quality

ADF %:

58.6% 14.6% 3.6% 1.9% 14.7% 33.0% 21.9% 33.0% 28.6% 14.7% 3.6% 18.0% 22.8% 19.8% 23.3% 16.1%
Weeds

- Most weeds lower the forage quality of alfalfa, particularly grasses
- Some weeds are quite high in forage quality
- Watch for nitrate! (labmsquarters, pigweed)
- Toxicity of particular weeds (fiddleneck, groundsel, noxious)
- Physical characteristics (burs, irritants) – in ability to cure (molds)
- Grassy weeds usually worse
- Perception (marketing)
### Grass Mixtures and Weeds -
#### Digestibility and Intake:

<table>
<thead>
<tr>
<th>Range</th>
<th>Crop</th>
<th>Digestibility</th>
<th>NDF</th>
<th>Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td></td>
<td>kg/d</td>
</tr>
<tr>
<td>Low</td>
<td>Grasses</td>
<td>48.8</td>
<td>74.5</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>Legumes</td>
<td>47.7</td>
<td>68.7</td>
<td>0.93</td>
</tr>
<tr>
<td>Med</td>
<td>Grasses</td>
<td>63.1</td>
<td>66.8</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Legumes</td>
<td>61.9</td>
<td>48.3</td>
<td>1.34</td>
</tr>
<tr>
<td>High</td>
<td>Grasses</td>
<td>71.8</td>
<td>60.4</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td>Legumes</td>
<td>72.2</td>
<td>43.7</td>
<td>1.52</td>
</tr>
</tbody>
</table>

(Data from Mertens, 1973)
Temperature/Environment

- **Spring/Fall Harvests** lower in fiber, higher in TDN and Protein than summer harvests
- **Cool Temperature** forage likely to be higher in Total Energy
- **High Temperatures Hasten Maturity**, and increase Plant Respiration, lower quality
- **Daily/hourly Changes** in quality?
Seasonal Changes in Crude Protein

(Fresno, CA – Ave. of 10 non-dormant varieties)

Crude Protein (%)

Cutting
Seasonal Changes in ADF
(Fresno, CA – Ave. of 10 non-dormant varieties)

ADF (%)

18 20 22 24 26 28 30 32 34 36

Cutting

1 2 3 4 5 6 7

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Daily Changes in Non-Structural Carbohydrates (sugars)

Data generated using model of Denison & Loomis, 1989

Day of Year:
April 20
June 30
Oct. 22
Effect of Time of Day on TDN

Shasta Co., California, 1994

Oven-dried Samples, Ave. of five varieties, 2-yr old stand
Statistically significant at 5% level.
Factors which influence Forage Quality:

(Leaves: 12-18% ADF, 22-30% CP)

(Stems: 28-45% ADF, 12-18% CP)

(Cell Solubles-(NSC) 100% digestible)

25-35% TDN

30-50% ADF/NDF

15-25% 

2-3%

8-13%

NON-STRUCTURAL CARBOHYDRATES
(NSC-Sugars, Starch, pectin)

STRUCTURAL CARBOHYDRATES
(NDF-Cellulose, hemicellulose, lignin)

PROTEINS (Soluble & bound)

OILS (lipids)

ASH (minerals)
Rain Damage

- Dry Matter Losses (leaching of cell solubles – TDN and soluble protein)
- Leaf Shatter
- Increased Respiration (cell solubles, microbial degradation)
## Rain Damage

<table>
<thead>
<tr>
<th>Loss</th>
<th>No Rain</th>
<th>1 inch</th>
<th>2.5 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Loss DM</td>
<td>---------</td>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>Leaf Shatter</td>
<td>7.6</td>
<td>13.6</td>
<td>17.5</td>
</tr>
<tr>
<td>Leaching &amp; resp.</td>
<td>2</td>
<td>6.6</td>
<td>36.9</td>
</tr>
<tr>
<td>Total Loss</td>
<td>9.6</td>
<td>20.2</td>
<td>54.4</td>
</tr>
</tbody>
</table>
Harvesting/Conditioning:

- Major effect on forage quality
- Drydown of stem vs. leaf (different rates)
- Loss of leaf material
- Raking/tedding is primary culprit, then baling
- Wide windrows help-rapid drying
- Vigorous conditioning important – rapid drying
- Improved balers
Table 1. Losses Due to Respiration

<table>
<thead>
<tr>
<th>Dry Matter Loss</th>
<th>2%</th>
<th>4%</th>
<th>8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Loss ($/t)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay value $239/t</td>
<td>$4.78</td>
<td>$9.56</td>
<td>$19.12</td>
</tr>
</tbody>
</table>

Forage Quality Loss from 4% sugar/starch loss

<table>
<thead>
<tr>
<th>ADF, %</th>
<th>NDF, %</th>
<th>RFQ</th>
<th>Value, $/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.0</td>
<td>40.0</td>
<td>153</td>
<td>$239.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33.0</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43.4</td>
<td>$125.00</td>
</tr>
</tbody>
</table>

Prices from Midwest Hay Market Report, Nov 6, 2015
Wide swath benefits

- Faster drying
- Higher forage quality
- Less respiration

Narrow windrow

Wide Swath

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**Hay Bleaching: No Effect on Quality**

### Treatment Results

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ADF</th>
<th>NDF</th>
<th>CP</th>
<th>dNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunbleached</td>
<td>32.8</td>
<td>38.1</td>
<td>20.2</td>
<td>39.1</td>
</tr>
<tr>
<td>Unbleached</td>
<td>32.6</td>
<td>38.5</td>
<td>19.7</td>
<td>38.8</td>
</tr>
</tbody>
</table>
# Leaf Retention - Rehydration

<table>
<thead>
<tr>
<th></th>
<th>Bale Moisture (% w.b.)</th>
<th>Losses (% of DM)</th>
<th>As-Baled Density (lb./ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam</td>
<td>8.6</td>
<td>0.5&lt;sub&gt;a&lt;/sub&gt;</td>
<td>18.6&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Dew</td>
<td>11.2</td>
<td>1.2&lt;sub&gt;b&lt;/sub&gt;</td>
<td>15.9&lt;sub&gt;a&lt;/sub&gt;</td>
</tr>
</tbody>
</table>


Kevin Shinners (UW) slide
Harvest Fractionation

- Harvest alfalfa leaves and stems separately:
  
  - Eliminates balancing of yield and quality
  - Fewer cuttings, optimized ration

Source: http://www.progressiveforage.com/forage-production/equipment/harvesting-alfalfa-leaves-separately-from-stems

2017 Forage Quality and Agronomic Practices
Harvest Fractionation

2017 Forage Quality and Agronomic Practices

Kevin Shinners (UW) slide
Fertilizers and Alfalfa Quality:

- Most fertilizers increase alfalfa yield (when element is limiting in soil)
- Little evidence of improved forage quality
- Better growth, of plants—stem growth
- Excess plant K a negative nutritional factor
- N fertilizers MAY increase CP but it is not usually economic. N fertilizers encourage weeds. This practice not recommended
- Fertilizers generally do not increase quality but are important for yield.
Pests & Diseases:

- Major effect is usually on percentage leaf – decrease in quality
- Leafhoppers may decrease stem growth, therefore increase quality but lower yield
- Alfalfa Weevils chew on leaves, so reduce alfalfa quality
- Honeydew (sooty mold), eg. Whitefly, aphids
- Stress from some diseases may reduce internodes, improving quality
- Effect on yield is primary consideration
Moisture Stress & Alfalfa Quality:

<table>
<thead>
<tr>
<th>Applied Water</th>
<th>ET (%)</th>
<th>Yield (t/a)</th>
<th>%TDN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>48</td>
<td>4.3</td>
<td>56a</td>
</tr>
<tr>
<td>42</td>
<td>75</td>
<td>7.9</td>
<td>54b</td>
</tr>
<tr>
<td>55</td>
<td>100</td>
<td>8.8</td>
<td>54b</td>
</tr>
<tr>
<td>70</td>
<td>125</td>
<td>8.6</td>
<td>53b</td>
</tr>
</tbody>
</table>

(data: V. Marble)

Message: Irrigate for high yields. Use other methods to obtain high quality.
Varieties:

- Some varieties are superior in quality (1-2 points) at same cutting schedule
- Not necessarily related to multi-leaf trait.
- Yield is most important for variety selection, then disease resistance, then quality potential
- Fall dormancy has an important effect on quality
- Watch yield penalty of so-called ‘high quality’ varieties (yield-quality tradeoff).
Variety, Quality and Yield

2002-2004 All Harvests

YIELD (Mg ha⁻¹)

FALL DORMANCY SCORE

Yield: \( y = -0.147x^2 + 2.6161x + 12.633 \)
\( R^2 = 0.7418 \)

Quality:

ADF: \( y = 6.1542x + 243.15 \)
\( R^2 = 0.9279 \)

Plumas
WL325HQ
54Q53
Dura 512
Tango
Archer II
Magna 601
Aspire
Acheiver
Sutter
Dura 765
SW 9720
WL625HQ
58N57
DS681FQ
WL711WF
CUF101
SW 7410

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Remember...

Yield (⁺) (⁻) Quality (⁺)

Stand Life (⁺)
Biotechnology & Breeding

Several Key Possibilities:

- Down-regulated lignin (deregulated 2015)
  - Lignin essentially useless nutritionally
  - Slowing decay of quality (preserve juvinility)
- Delayed flowering/maturity
- Improvements in protein nutrition
  - Protein is poorly utilized in alfalfa
  - Tannins – temporary binding
  - Polyphenol Oxidase - silage
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D.H. Putnam, UC Davis

CUTTING SCHEDULE
HARVEST MANAGEMENT
VARIETY
WEEDS
PESTS
SOIL TYPE, FERTILITY
IRRIGATION

Accurately Sample & Test!
The Sampling Dilemma
Does This Represent 200 Tons?
Summary:

- **Primary Mechanisms:**
  - plant maturity at harvest
  - leaf/ stem ratio
  - percentage weeds
  - weather/temperature/season

- **The most important Effects on Quality**
  - harvest management (cutting schedule, conditioning, leaf retention in the baling process)
  - Weed Management (elimination of poor quality weeds)
Summary (cont.):

- Some Effect on Quality:
  - Variety
  - Afternoon harvests
  - Controlling pests
  - Soil Type

- Not as important:
  - stand density, irrigation, or fertilizers

- Watch for further innovations in
  - harvesting technology (rapid drying, leaf retention)
  - genetics and biotechnology
  - weed control, and harvest management strategies
“They’ve got to work on those faculty salaries”
What is the first step in taking a representative hay sample?

Identify a ‘lot’ of hay –
Consisting of one field, single cutting, no more than 200 tons
Is there variation due to sampling? How much?

Minimum Variation:

+/- 0.5% CP
+/- 0.7% ADF
+/- 1.0% NDF

No Sample Value is Absolute!

Sources of Variation:

Sampling (the most important)
Sample handling
Lab Analysis (normal daily variation)
Lab/Lab Differences, bias
CUTTING SCHEDULE
HARVEST MANAGEMENT
VARIETY
WEEDS
PESTS
SOIL TYPE, FERTILITY
IRRIGATION

Accurately Sample & Test!
What Practices Create Quality in Alfalfa?
(Leaves: 12-18% ADF, 22-30% CP)

(Stems: 28-45% ADF, 12-18% CP)

(Cell Solubles-(NSC) 100% digestible)

(Cell Wall (NDF) - 0-60% digestible)

25-35% TDN

30-50% ADF/NDF

15-25% TDN

2-3%
8-13%

NON-STRUCTURAL CARBOHYDRATES (NSC-Sugars, Starch, pectin)

STRUCTURAL CARBOHYDRATES (NDF-Cellulose, hemicellulose, lignin)

PROTEINS (Soluble & bound)

OILS (lipids)

ASH (minerals)

Whole Plant
Plant Cell
Whole Plant Analysis
Agronomic Factors:

- Cutting Schedules
- Rain Damage
- Harvest Effects
- Variety
- Stand Density
- Soil Type/Fertility
- Irrigation
- Pest Interactions
Biotechnology & Breeding

- **Several Key Possibilities:**
  - Down-regulated lignin (deregulated 2015)
    - Lignin essentially useless nutritionally
    - Slowing decay of quality (preserve juvinility)
  - Delayed flowering/maturity
  - Improvements in protein nutrition
    - Protein is poorly utilized in alfalfa
    - Tannins – temporary binding
    - Polyphenol Oxidase - silage