Value Added Uses For Alfalfa

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Value Added Use of Alfalfa

- Alfalfa production: trends and uses
- Environmental impact of alfalfa in crop rotations
- Future innovations needed to maintain or expand alfalfa acreage
2004 U S Alfalfa Production

- Hay
  - 75.4 million tons
  - 21.7 million acres
  - $7.0 billion
  - 3rd following corn and soybeans

- Forage
  - 83.9 million tons
  - 24.7 million acres
  - ~$8.2 billion
  - 3rd following corn and soybeans
Leading Alfalfa Hay States, 1,000 acres, 2004

Top 10 States
- 63 % of U. S.
- 59 % of Acre
- 7 states NC
- 3 states West
- 4 Lead Dairy
U. S. Alfalfa Hay in 1,000 tons

Acreage

Production
Alfalfa Enhancing Nutrient Management

- Adds nitrogen via biological fixation
- Protects surface and ground water
- Improves water infiltration and soil quality
- Eliminates soil erosion from wind and water
- Improves yield of subsequent crop
Dinitrogen Fixation:

- Symbiosis of *Rhizobium meliloti* with alfalfa
- N₂ Fixation contributes 165 million tons of N to the earth each year.
- Over 6 million tons of N fixed by crops, 1/3 by alfalfa
- Eliminates need for N fertilizers in alfalfa.
**N₂ Fixation is Valuable through:**

**Reduction in need for N fertilizers:**

- About 80 million tons of alfalfa were produced in the US in 2001.
- At 20% CP, and 75% of N supplied through fixation this is about **2 million tons of N** from fixation.
- A **minimum** of this amount of N fertilizer would be required to replace the N contributed by N₂ fixation of alfalfa, to produce the same quantity of protein.
N$_2$ Fixation is Valuable through:

Providing N to subsequent crops

- Typically an N credit of 50-170 lbs/acre given to corn
Deep-Rooted Characteristics of Alfalfa:

- Protects soil from erosion through vigorous below-ground root structure
- Protects soil surface with vigorous canopy
Deep-Rooted Characteristic of Alfalfa:

- Alfalfa roots have been measured to 39 meters (over 100 feet), but 5 m is common
- Nutrient Cycling
- Soil structure - soil structure
Alfalfa: Sponge for Nitrate

- New alfalfa developed to fix N from soil not from atmosphere which increases effectiveness as nitrate absorber
- New alfalfa developed for rapid root growth to quickly capture nutrients
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
USDA-ARS Plant Science Research Unit
St. Paul, MN

From the gene ... to the landscape

Molecular Biology

Adaptation and Productivity

Feed Quality

Environmental Stewardship

New Uses
Genomics and Gene Expression:

- Key player in the international *Medicago* genomics program
- Characterized plant genes for nitrogen fixation and disease resistance
- Isolated and characterized genes for carbon and nitrogen metabolism

Disease Resistance and Stress Tolerance:

Developed alfalfa germplasms with better

- disease resistance
- aluminum tolerance
- manure tolerance

and for phytoremediation of

- nitrate
- atrazine
- heavy metals
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
Use Biotechnology in Alfalfa

- Enhance yield
- Forage quality improvements
- Environmental enhancements
- New products
Value-Added Traits of Alfalfa

- Value-added processing of alfalfa
- Transgenic high phytase alfalfa
- Potential products from dry fractionation
- Limitations to Biotech trait applications
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

**Wet**
- Herbage
  - Juice
  - "Fiber"
  - Enzymes (Transgenic)

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

**Animal**
- Herbage
  - "Digestibles" (to animal)
  - Fibrous Fraction
    - Hardwood
    - "Masonite"
    - Biofilters
    - Bio plywood
Potential new uses of alfalfa

- Electric generation
- Protein production
Development of Green Genes

- Fractionation of alfalfa
  - dry - electricity
  - wet - phytase
    - cellulase
    - biopluping
    - biobleaching
    - bioremediation
Build-up of Phosphorus in the environment and resulting degradation of water resources are of mounting concern.

Much of build-up is traceable to human activities-livestock production.

Mongastric animals, such as poultry and swine, which can solublize only a small fraction of Phosphorus in their grain-based diets while excreting the remainder, have come under incrased scrutiny. Supplementation of inorganic P into diet exacerbates problem.
High Phytase Transgenic Alfalfa

- Much of phosphorus in grain is in form of insoluble phytates.
- Research has shown supplementing poultry and swine diets with the enzyme phytase can lead to solubilization of the phosphorus; thus, eliminating the need for supplemental phosphorus and reducing current phosphorus levels in animal excrement to approximately one-half of normal.
- Enzyme Phytase derived from *Aspergillus niger* has to date been produced using genetically engineered microorganisms.
Transgenic Phytase-rich Alfalfa

- Phytase enzyme makes P in grain ration of monogastric diets more available (poultry, swine, and fish)
- 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
Gain on Phytase (800 units/Kg ration) without phosphorus supplementation

Phosphorous content of ration without supplementation of inorganic P

Gain (g) 3 Weeks

% Phosphorus in Ration
Inorganic P Supplementation

No Supplementation

0.4% P 0.55% P 0.85% P

Transgenic Alfalfa Phytase

Juice Leaf Meal

Commercial Phytase

Phytase

Juice

Leaf Meal

Commercial Phytase

0.711 0.712 0.895 0.816 0.829 0.847 0.775 0.845 0.796 0.790

300 units 600 units 400 units 200 units
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
Protein extraction

- Extract is 55% protein
- Good balance of trace minerals
- High in xanthophyll
Bio-degradable plastics made from Lactic Acid
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
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
Dry Fractionation of Alfalfa Hay

- Fractionation of alfalfa
  - dry - electricity
Dry Fractionation of Alfalfa Hay

Ag dependent electric power production must be:

- sustainable
- in energy balance
- developed with new power generation
- efficient production systems
Minnesota Valley Alfalfa Producers

Farmer-owned Coop at Granite Falls

- ag region of corn, soybeans, and sugar beets
- public-private effort to develop $200 mil alfalfa processing & biomass energy system by 2001

- produce and process 750,000 tons alfalfa/year
  - produce various high value products
  - generate 75 megawatts power
Minnesota Valley Alfalfa Producers

- Poll for 4 stock offerings
- Selected by Department of Energy
- Signed Power Purchase Agreement
- Public utilities commission reversed power purchase agreement
## Nutrient Composition of Alfalfa Hay

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Total</th>
<th>Pan</th>
<th>Stems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leaves</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>25.2</td>
<td>28.1</td>
<td>12.1*</td>
</tr>
<tr>
<td>NDF</td>
<td>36.0*</td>
<td>32.9*</td>
<td>63.1*</td>
</tr>
<tr>
<td>IVDDM</td>
<td>73.5*</td>
<td>73.5*</td>
<td>53.8*</td>
</tr>
</tbody>
</table>

* Quality varied between grades

* DM = Dry Matter
# Nutrient Composition of Leaf Meal from Fractionation

<table>
<thead>
<tr>
<th>Component</th>
<th>Separation</th>
<th>Mechanical</th>
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<tbody>
<tr>
<td></td>
<td>Lab  ‘96</td>
<td>‘98</td>
</tr>
<tr>
<td>Crude protein</td>
<td>25.2</td>
<td>28.1</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>

---% of dry weight----

## Effects of Substituting Alfalfa Leaf Meal for Alfalfa Hay

<table>
<thead>
<tr>
<th>Diet</th>
<th>ALM substitution for alfalfa hay, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>0</td>
</tr>
<tr>
<td>Corn silage</td>
<td>25.8</td>
</tr>
<tr>
<td>Alfalfa hay, chopped</td>
<td>25.9</td>
</tr>
<tr>
<td>ALM pellets</td>
<td>--</td>
</tr>
<tr>
<td>Concentrates</td>
<td>48.3</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>28.0&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milk, kg/d</td>
<td>38.9</td>
</tr>
</tbody>
</table>

**SOURCE:** Jorgenson, 1998
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
Potential new uses of alfalfa

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

1. Grind
2. Pretreatment to Remove Inhibitors
3. Enzymatic Breakdown of Polysaccharides
4. Sugars
5. Fermentation
6. Ethanol Recovery
7. Electricity & Processing Heat
8. Residual Solids
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

Graph showing the moisture percentage of whole plant and stripped stems over time from 11:00 AM to 5:00 PM.
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
Fiber Board and Filter Mats from Manure

Thick Filter Mat

Fiber Board

Thin Filter Mat
Potential new uses of alfalfa

- Electric generation
- Protein production
- Ethanol production
Alfalfa New Product Initiative: The French Connection

Right: Travelling 12 mph, this French harvester fills a 30' trailer in seven minutes.
Below: Four of the 30+ feed products made by the French co-op.

PHOTOS: RUDY BADKE NON
Limitations to Biotech Trait Applications

- Potential for alfalfa is tremendous
- Value added traits require large investments in processing facilities
- The set-back of Minnesota Agra Power Project
- Processors need to think outside the “box”
- Public and private research need cooperation and corporate support
Value-Added Traits of Alfalfa

Summary and Conclusions

- Genetically modified alfalfa can be processed to provide alfalfa 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.