

U.S. Dairy Forage Research Center

USDA, Agricultural Research Service

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 acre
- \$ 7.0 billion
- 3rd following corn and soybeans

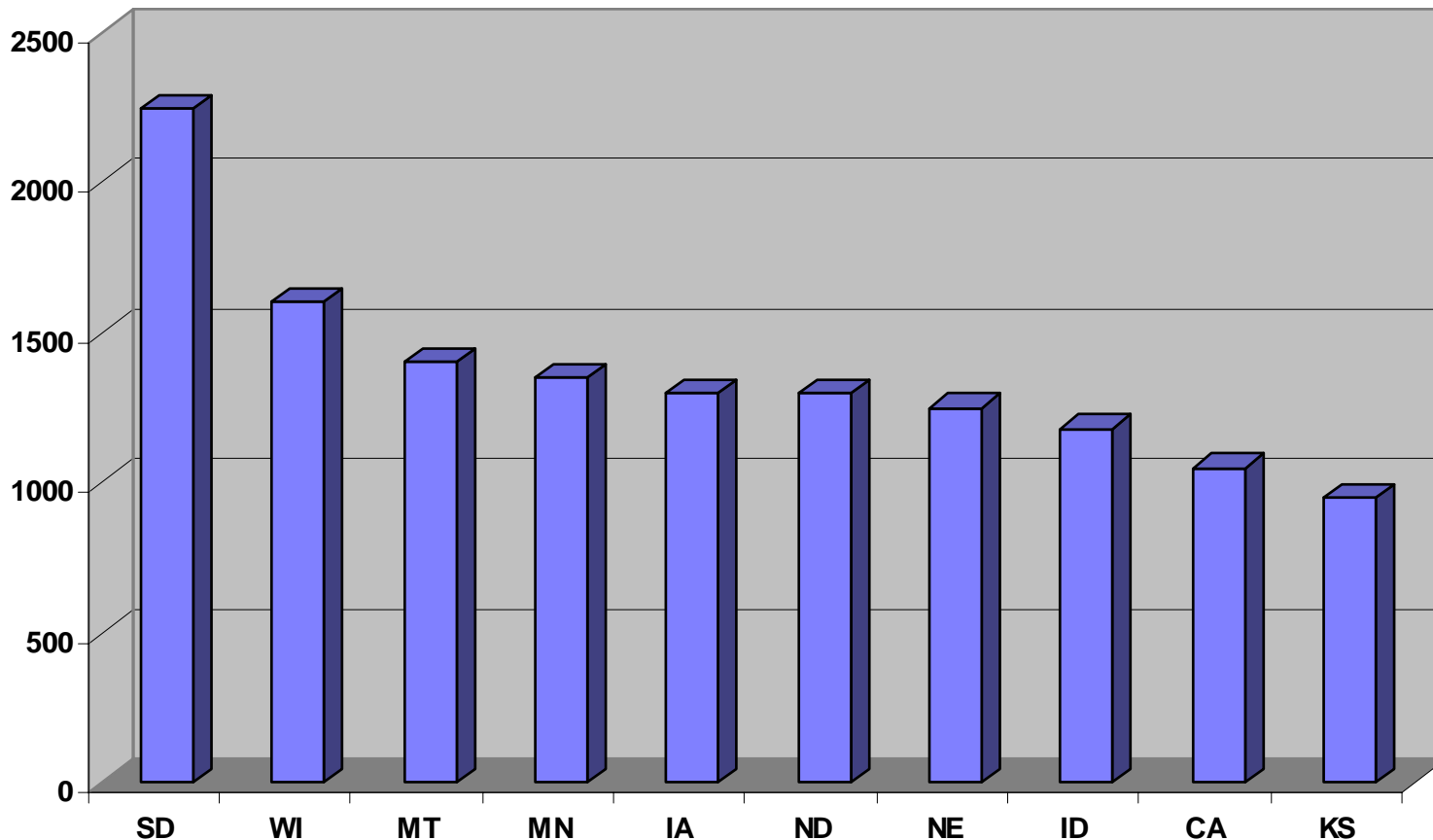
■ Forage

- 83.9 million tons
- 24.7 million acres
- ~\$8.2 billion
- 3rd following corn and soybeans

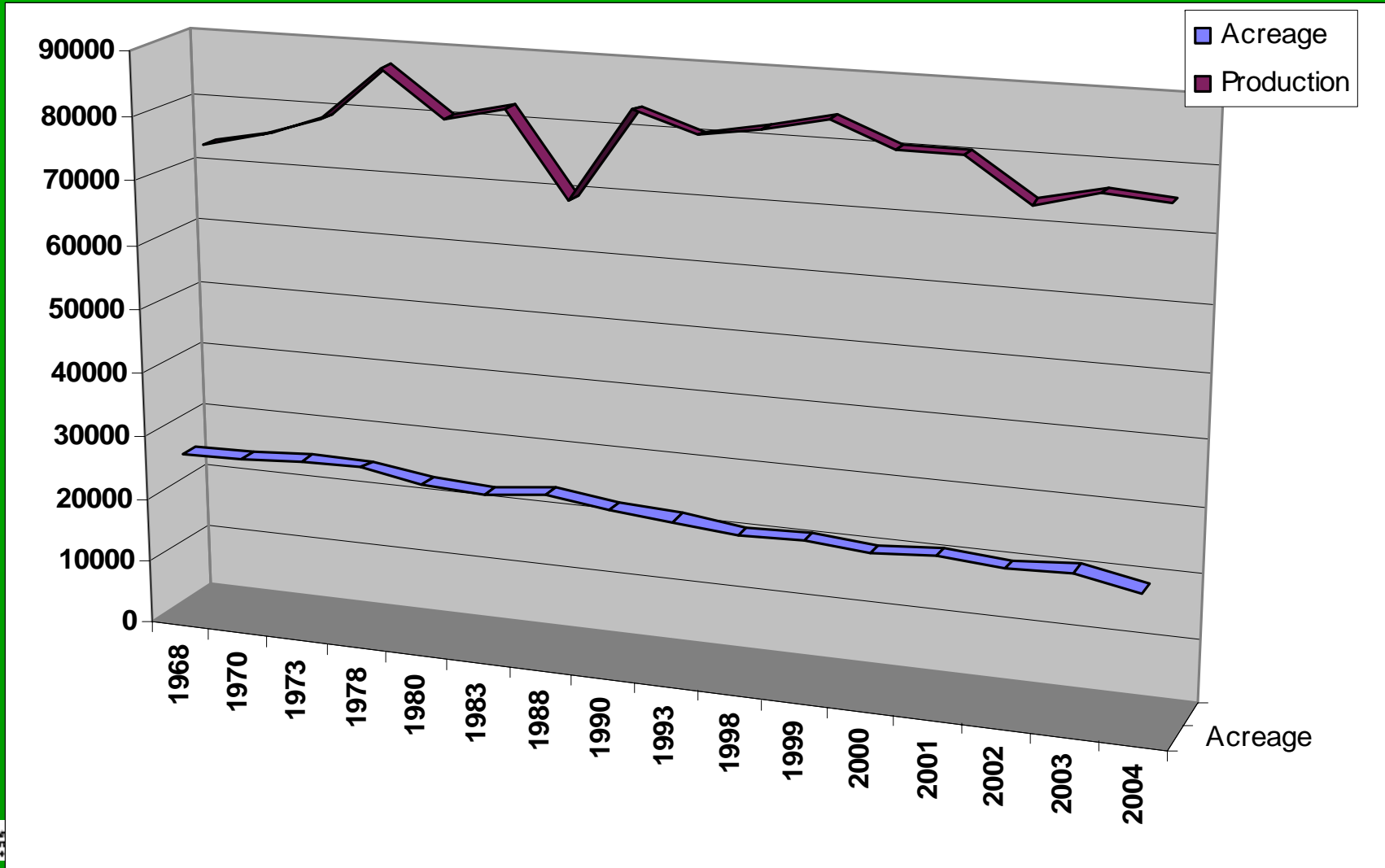
Leading Alfalfa Hay States, 1,000 acres, 2004

■ 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



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.

N₂ 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

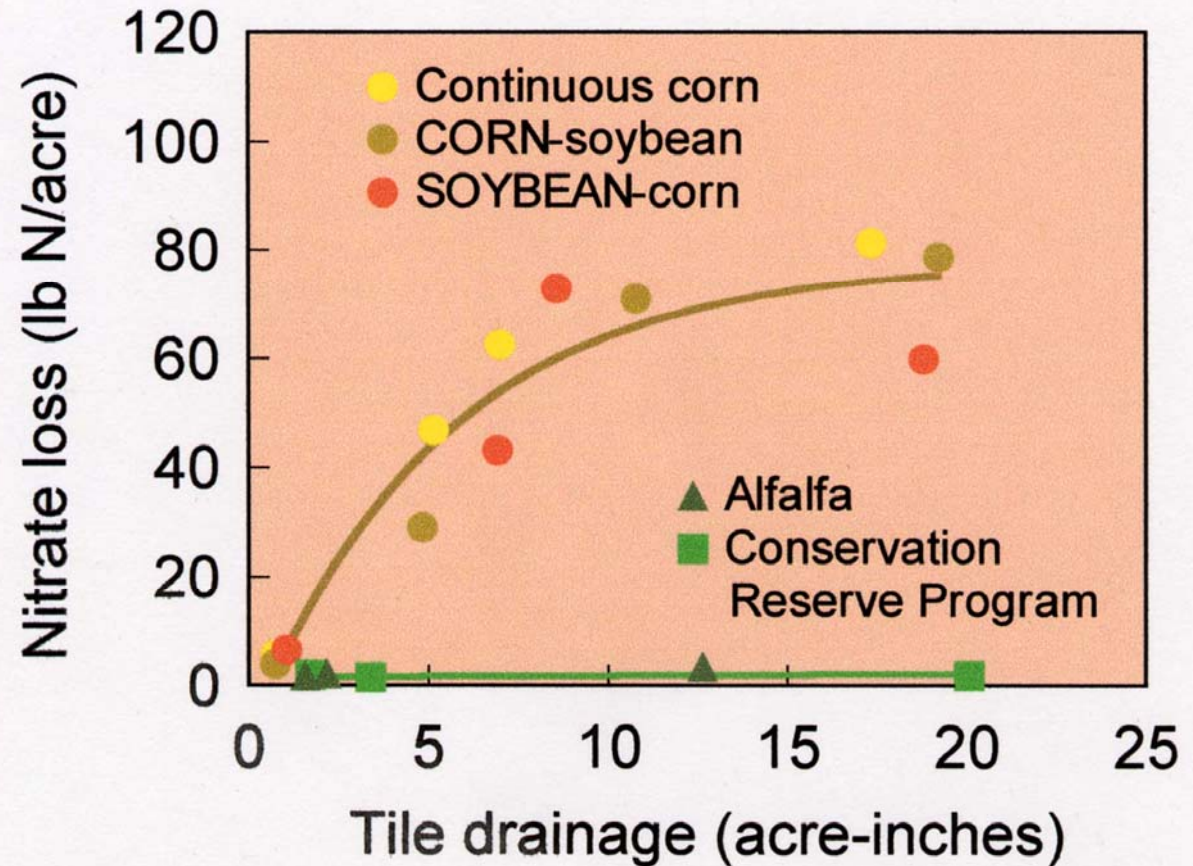


Alfalfa: Sponge for Nitrate

- 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



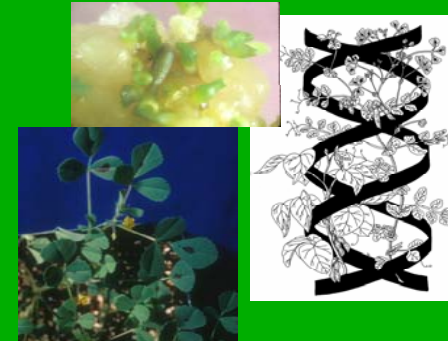
>40 million acres are tile drained
in the Upper Midwest

USDA-ARS Plant Science Research Unit St. Paul, MN



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



Reconstituted bales are sold year-round to French dairy farmers.



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

Novel Products of Alfalfa

- **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.**

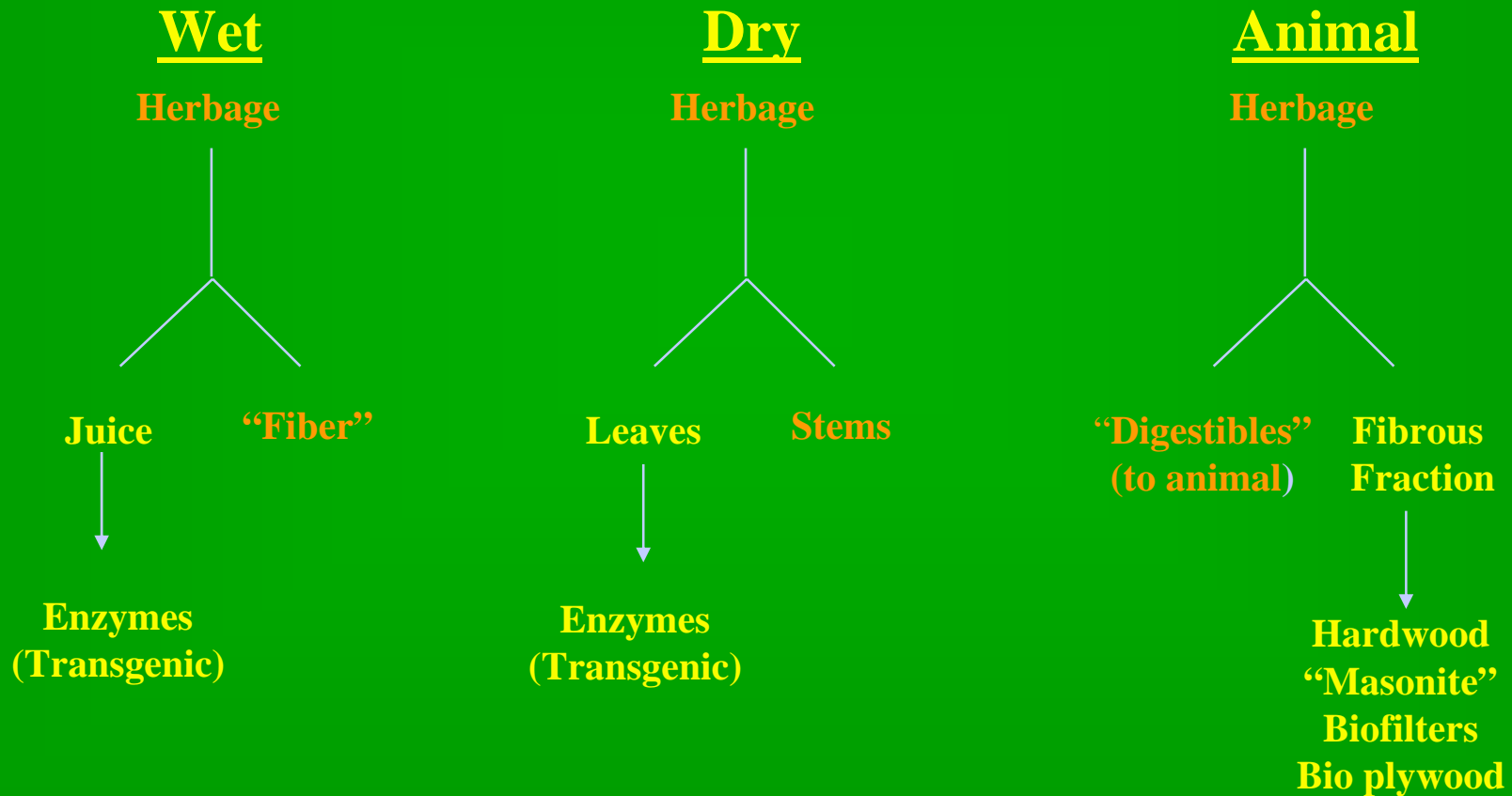
Novel Products of Alfalfa

- **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.**

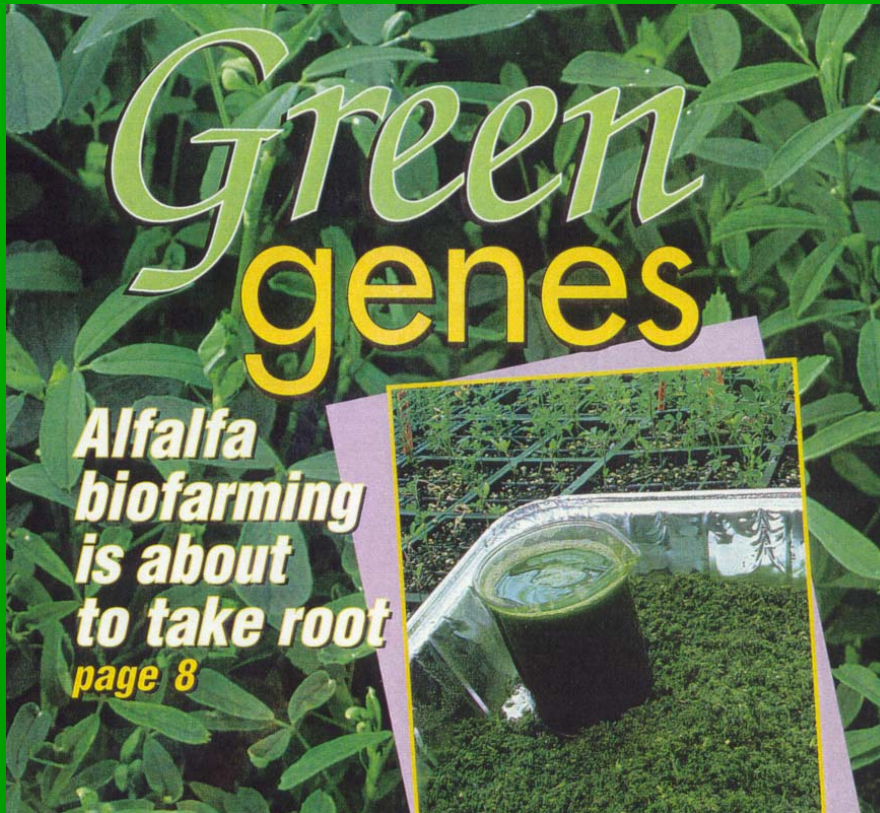
FRACTIONATION METHODS



Potential new uses of alfalfa

- **Electric generation**
- **Protein production**

Development of Green Genes



- Fractionation of alfalfa
 - dry - electricity
 - wet - phytase
 - cellulase
 - bioplumping
 - biobleaching
 - bioremediation

High Phytase Transgenic Alfalfa

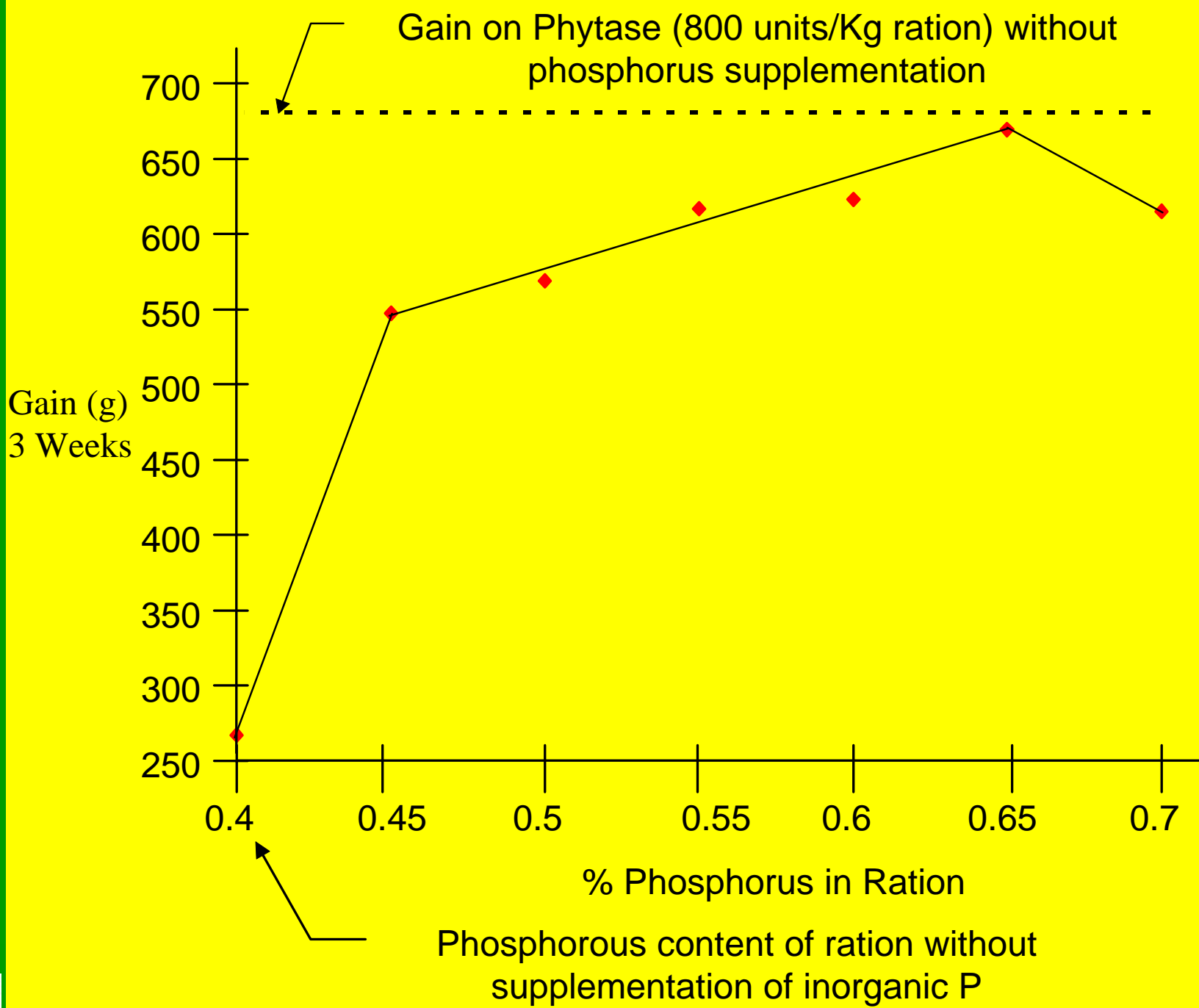
- **Build-up of Phosphorus in the environment and resulting degradation of water resources are of mounting concern.**
- **Much of build-up is traceable to human activities-livestock production.**
- **Ruminant animals, such as poultry and swine, which can solublize only a small fraction of Phosphorus in their grain-based diets while excreting the remainder, have come under increased scrutiny. Supplementation of inorganic P into diet exacerbates problem.**

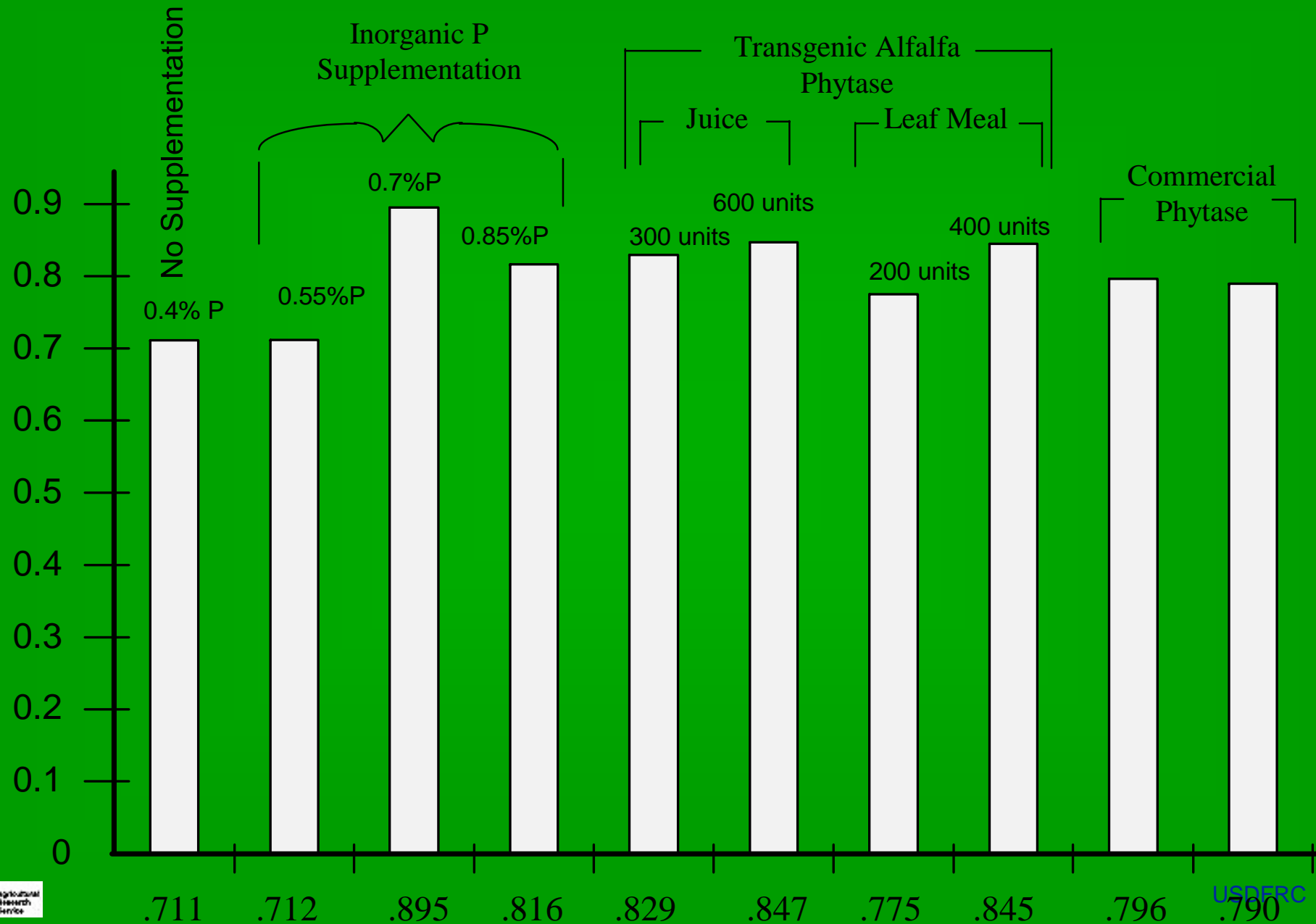
High Phytase Transgenic Alfalfa

- 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





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**

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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**

French May Produce Hemoglobin In Alfalfa Plants

Farmers in France may soon be growing alfalfa to produce human hemoglobin.

Viridis, a subsidiary of Alfalis, which specializes in alfalfa production, hopes to begin manufacturing various proteins, especially hemoglobin.

"Alfalfa is a true protein factory," says Damien Levesque, Viridis' managing director. "It is the plant that can produce the largest quantity of proteins per acre – far ahead of soybeans. Alfalfa produces 2,200 lbs of protein per acre, compared with 650 to 890 lbs for soybeans."

His company specializes in the extraction of alfalfa juice for pigments and other products.

"The special characteristic of alfalfa is storing the proteins in the leaves and not in the seeds like soybeans or peas," says Levesque. "Extraction is therefore carried out by pressing the green foliage in order to recover proteins in the alfalfa juice without altering its quality. We have developed a specific technology for pressing."

Viridis has acquired Medicago, a Quebec biotechnology company that successfully introduced the gene for hemoglobin production in alfalfa plants.

Fresh Alfalfa

Juice

Heat coagulate

Protein Concentrate

Poultry supplement or calf-replacer

25 % of original crop dry matter

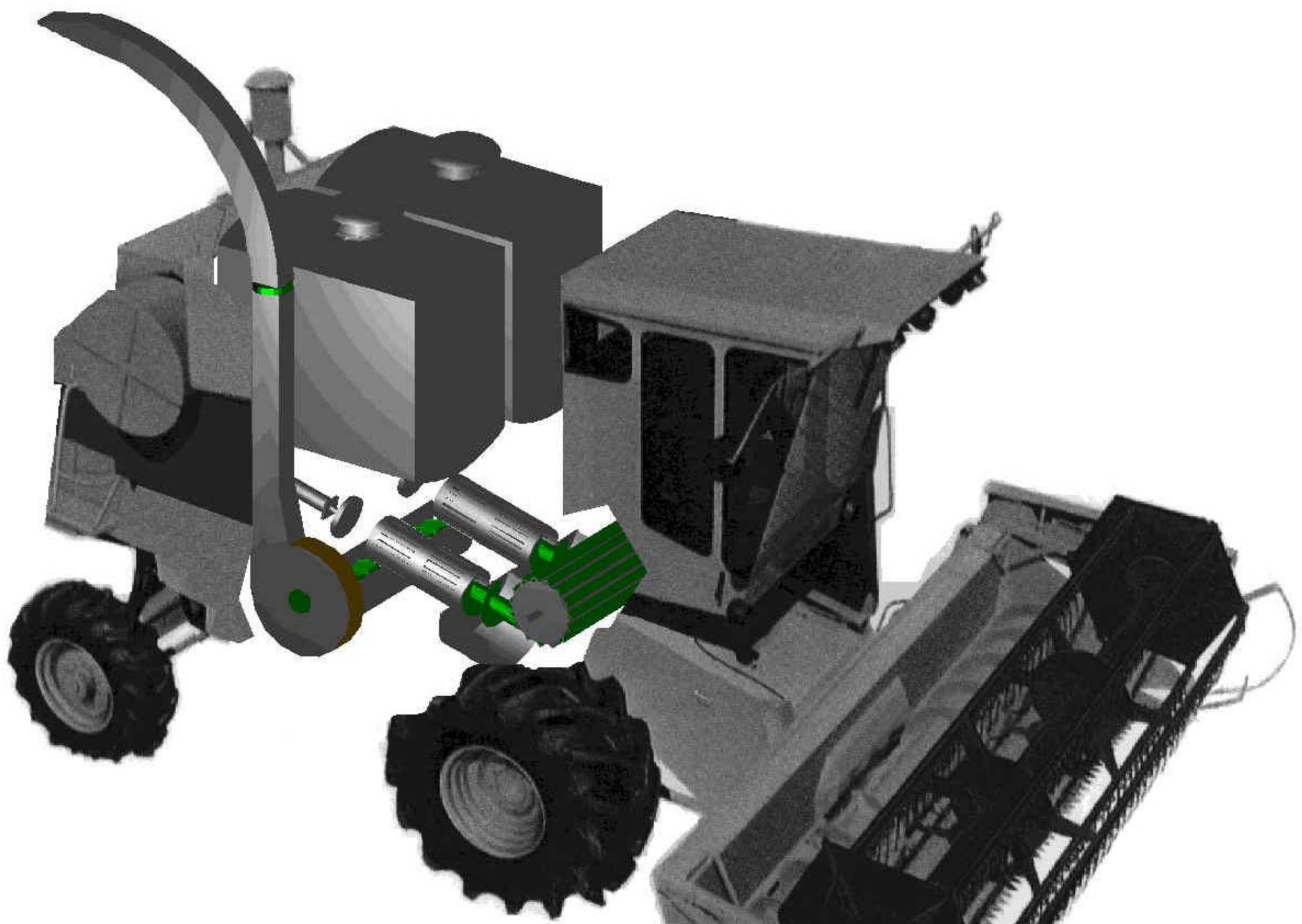
High fiber

Ruminant feed

- Store silage in bunkers
- Process fiber

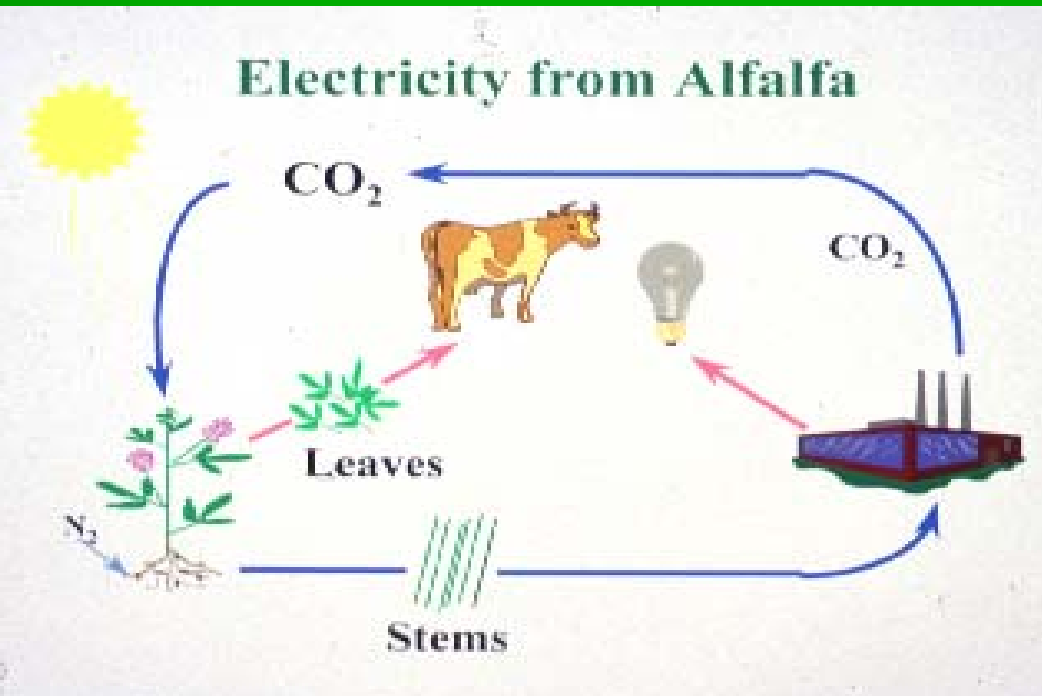
New products

75 % of original crop dry matter

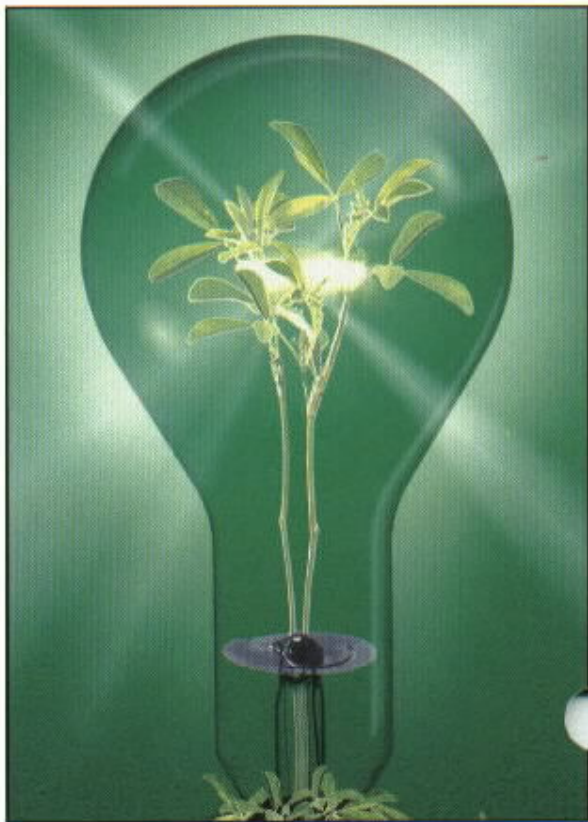


Dry Fractionation of Alfalfa Hay

- Fractionation of alfalfa
 - dry - electricity



Dry Fractionation of Alfalfa Hay



Biomass Power for Rural Development

DOE and USDA are collaborating to pursue the development and ultimate commercialization of biomass energy systems for the purposes of positively impacting global climate change and the revitalization of rural America.

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

Nutrient	Total	----- Leaves -----	
		Pan	Stems
		----- % of DM -----	
Protein	25.2	28.1	12.1*
NDF	36.0*	32.9*	63.1*
IVDDM	73.5*	73.5*	53.8*

* Quality varied between grades

Nutrient Composition of Leaf Meal from Fractionation

Component	Separation		Mechanical	
	Lab	'96	'98	'98
	-----% of dry weight----			
Crude protein	25.2	28.1	25.8	28.2
NDF	36.0	36.5	43.6	34.4
ADF	21.5	21.9	26.6	25.1
Ash	--	11.3	12.4	14.8

SOURCE: DiCostanzo et al. 1999.

Effects of Substituting Alfalfa Leaf Meal for Alfalfa Hay

Diet Composition	<u>ALM substitution for alfalfa hay, %</u>		
	0	28	56
Corn silage	25.8	26.0	26.0
Alfalfa hay, chopped	25.9	18.5	11.5
ALM pellets	--	7.9	15.8
Concentrates	48.3	47.6	47.0
DMI, kg/d	28.0 ^{cd}	29.3 ^c	26.7 ^d
Milk, kg/d	38.9	39.8	39.6

SOURCE: Jorgenson, 1998

Dry Alfalfa

Leaf Meal

High fiber

Protein Supplement

Dairy, beef, and Poultry

40-50 % of ground hay

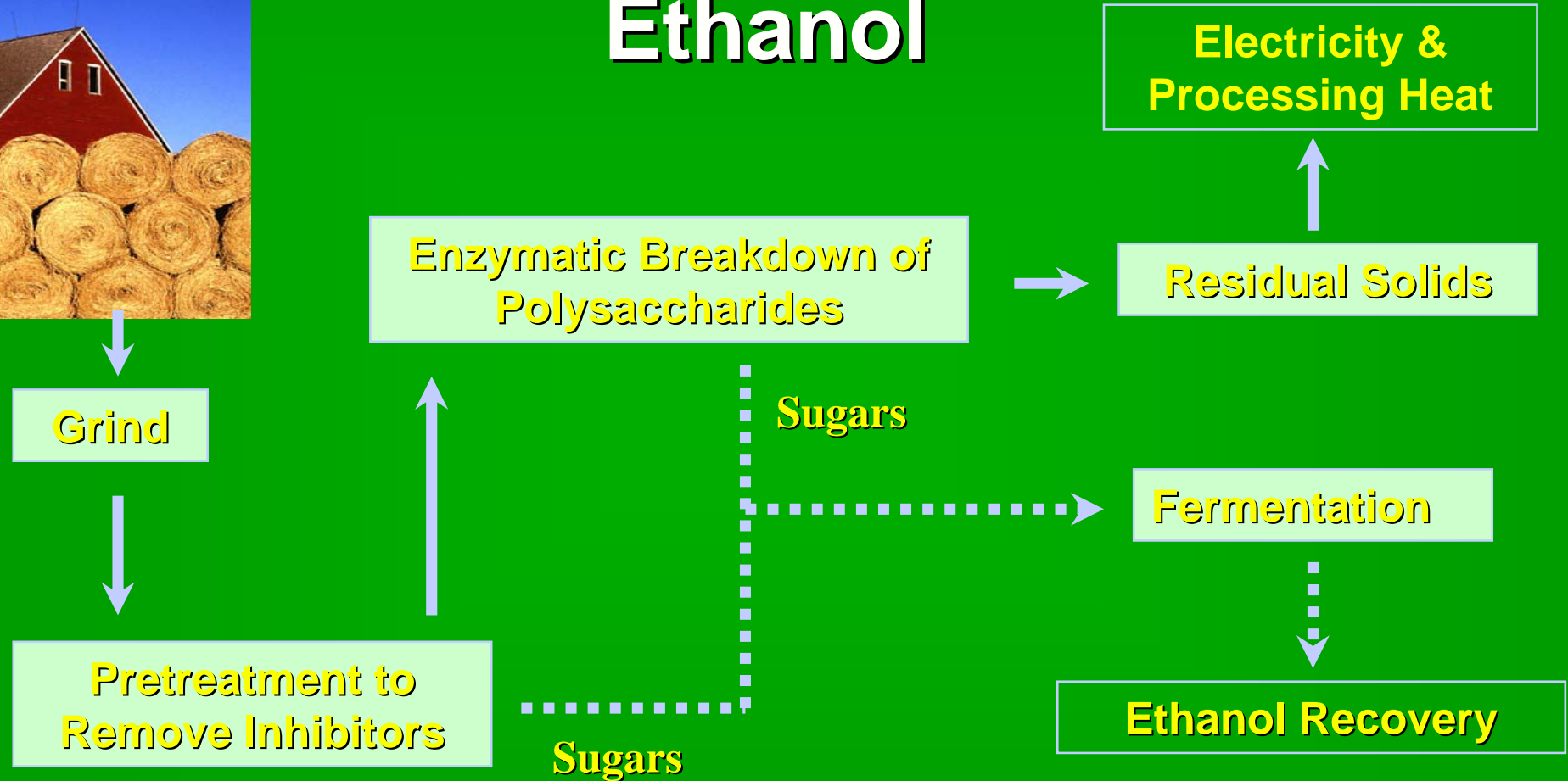
**Combustion, Gasification
Or Enzymatic Hydrolysis**

50-40 % of ground hay

Potential new uses of alfalfa

- **Electric generation**
- **Protein production**
- **Ethanol production**

Biomass Conversion to Ethanol



Fractionating for Quality

■ Alfalfa fractionating at harvest:



Fractionating for Quality

- Alfalfa fractionating at harvest:



Fractionating for Quality

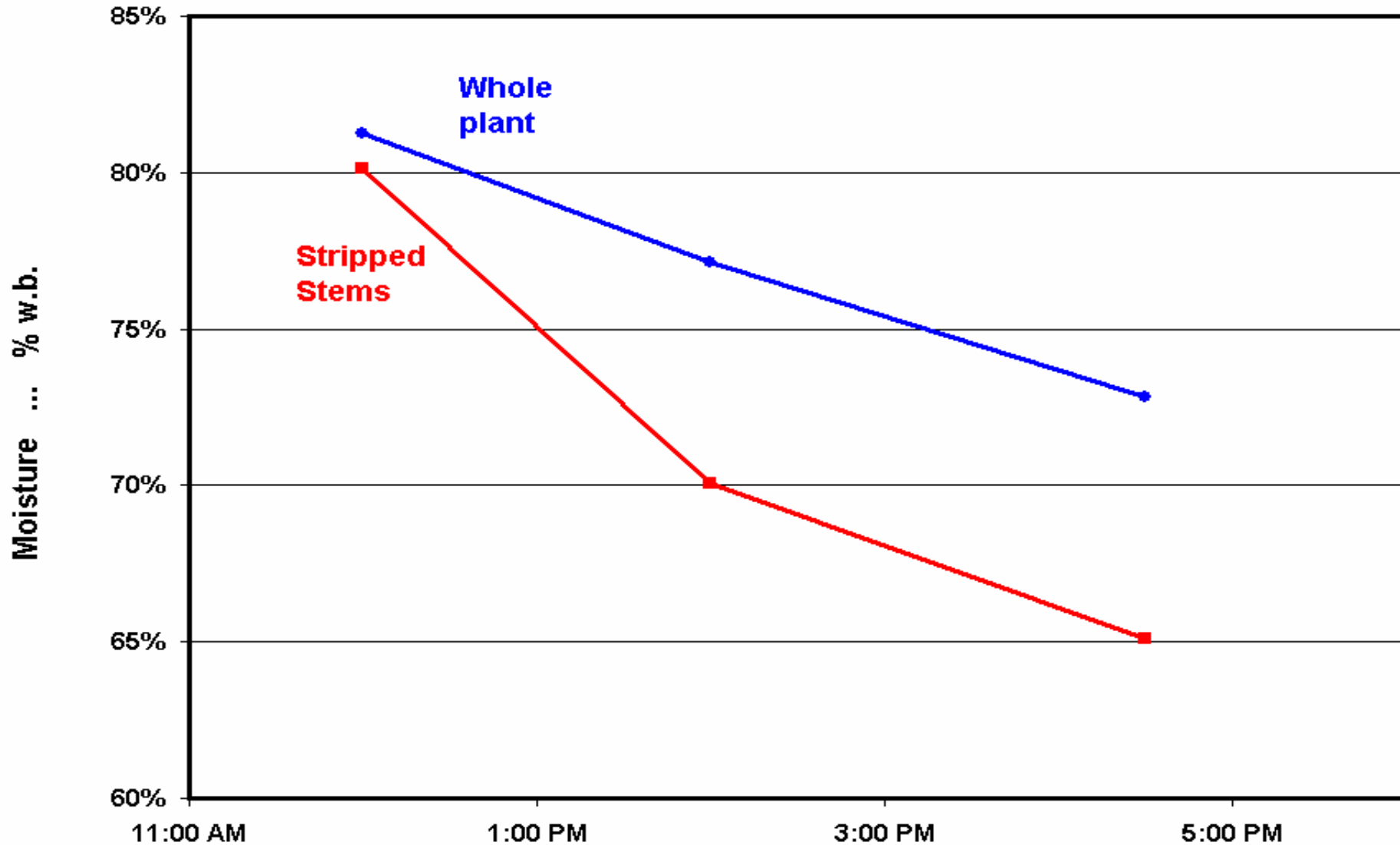
■ Why fractionate alfalfa at harvest:

- 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



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



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 RADKE, ND6U



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.