# Food and Fuel:
## Integrating animal feed production with cellulosic biofuels

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# Outline

- Introduction
  - Land use as a constraint
  - Land for human food vs animal feed
- Improved forages
  - AFEX results
  - Value of AFEX treated feeds
- Leaf protein concentrates
  - Effect on ethanol production
  - Optimization
- Conclusions

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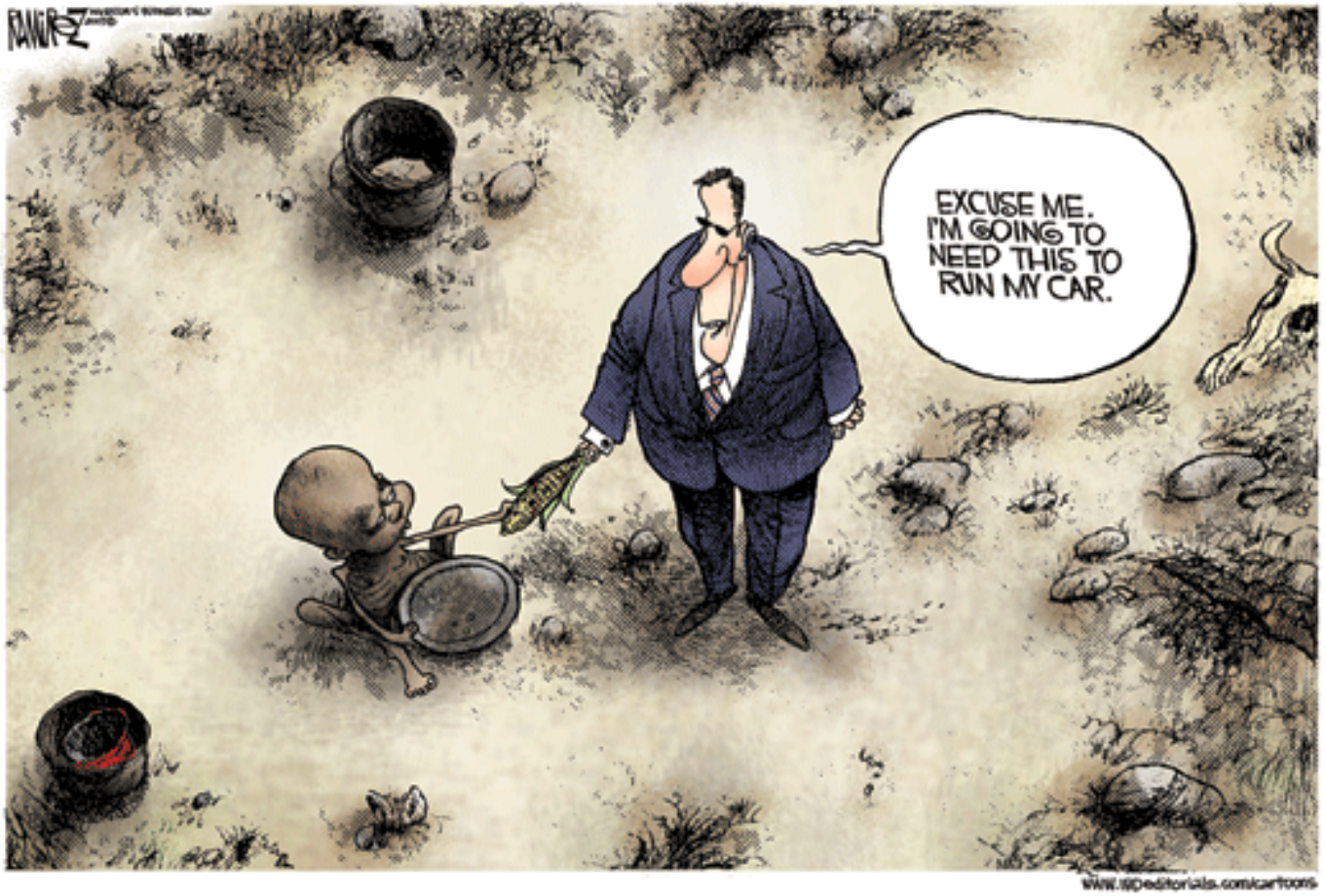
# Biofuels: A crime against humanity?




- "[I]t's a crime against humanity to convert agricultural productive soil into soil… which will be burned into biofuel."
  - Jean Ziegler, UN Special Rapporteur, 2007

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# Indirect land use change – are biofuels no longer sustainable?

| Source of fuel | Gasoline | Biomass ethanol | Biomass ethanol + indirect land use change |
|---|---|---|---|
| Feedstock | 4 | 10 | 10 |
| Refining fuel | 15 | 9 | 9 |
| Vehicle operation (burning fuel) | 72 | 71 | 71 |
| Feedstock carbon uptake from atmosphere (GREET) | 0 | -62 | -62 |
| Land-use change | - | - | 111 |
| Total GHGs | 92 | 27 | 138 |
| % Change in net GHGs versus gasoline | - | **-70%** | **50%** |

**All values are in g CO2 eq / km driven**

**Searchinger et al, (2008) Sci 319: 1238-1240**

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# Food vs Fuel or Feed vs Fuel?

- We currently do not maximize land use for either food OR biofuel production
- Our crops are primarily used to feed animals, NOT people
- Domestic cattle requirements:
  - $7.1 \times 10^{11}$ Mcal/yr (65 million acres corn eq)
  - $3.5 \times 10^{7}$ Mg protein/yr (76 million acres soy eq)
- Total animal feed requirements in the United States are an **order of magnitude** greater than human dietary needs

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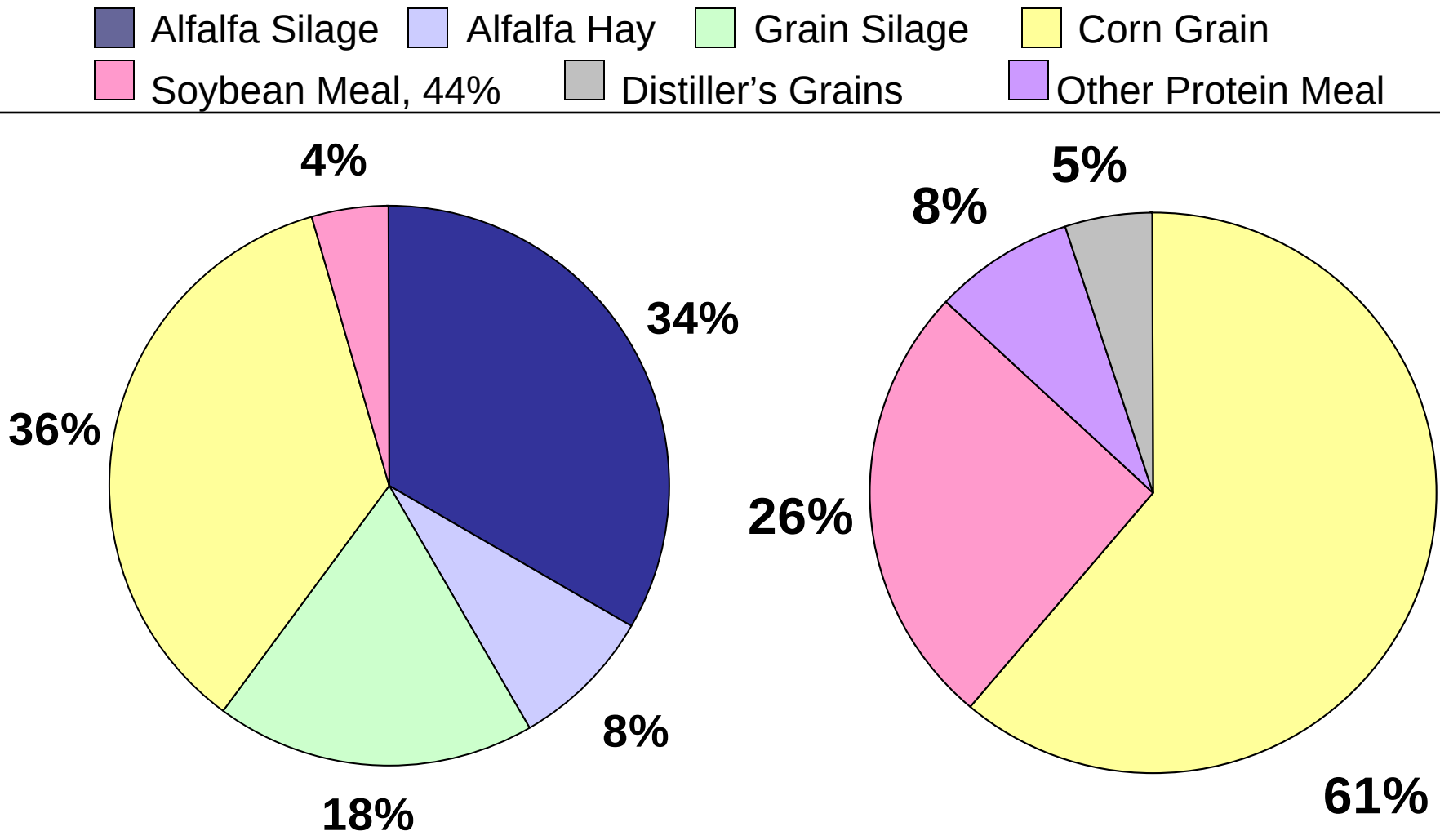
# Typical Animal Diets



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# Two Solutions

- Solution One: we all become vegans
- Solution Two: we feed our animals in a more land-efficient manner
  - Energy
    - Corn: 2.74 Mg starch/acre
    - Switchgrass: **2.7 – 5.3** Mg fiber/acre (current yields)
  - Protein
    - Soybean: 0.46 Mg protein/acre
    - Switchgrass: **0.12 – 0.54** Mg protein/acre
    - Cover crops: **0.33 - 0.49** Mg protein/acre
  - Dedicated energy crops must be processed prior to animal feeding – more expensive!
    - Solution: Co-producing with biofuels

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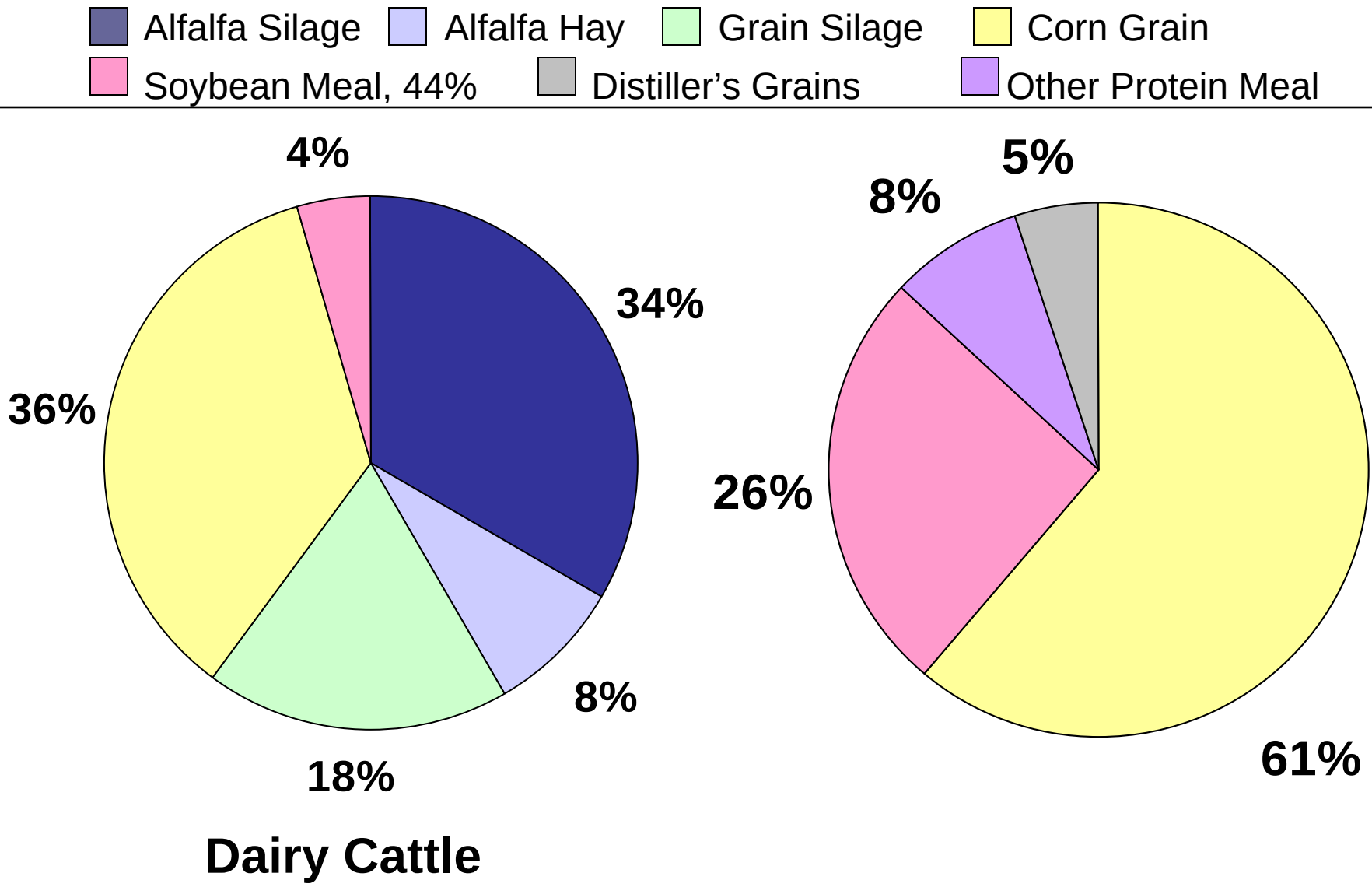
# Typical Animal Diets



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# Alternatives for cattle feeding

- Problem: Energy in the form of cellulose
  - Early Forages – low yields, expensive
  - Late Forages – indigestible, low nitrogen
- Partial solution: Gaseous ammoniation
  - Only modest improvements in digestibility seen
  - Increases nitrogen content
- AFEX – Ammonia Fiber Expansion
  - A leading pretreatment for biofuels via sugar platform
  - Much more extreme fiber disruption than conventional ammoniation for forages

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# In vitro Rumen Digestion

- Neutral detergent fiber (NDF) Digestion
  - Cellulose, hemicellulose, lignin
- Biomass placed in buffer solution and innoculated with rumen fluid of lactating dairy cow
  - Rumen microbes used to digest biomass
- 48h digestion
- AFEX vs untreated for 10 feedstocks
  - Traditional forages for feeding
  - Agricultural residues
  - Expected dedicated energy crops

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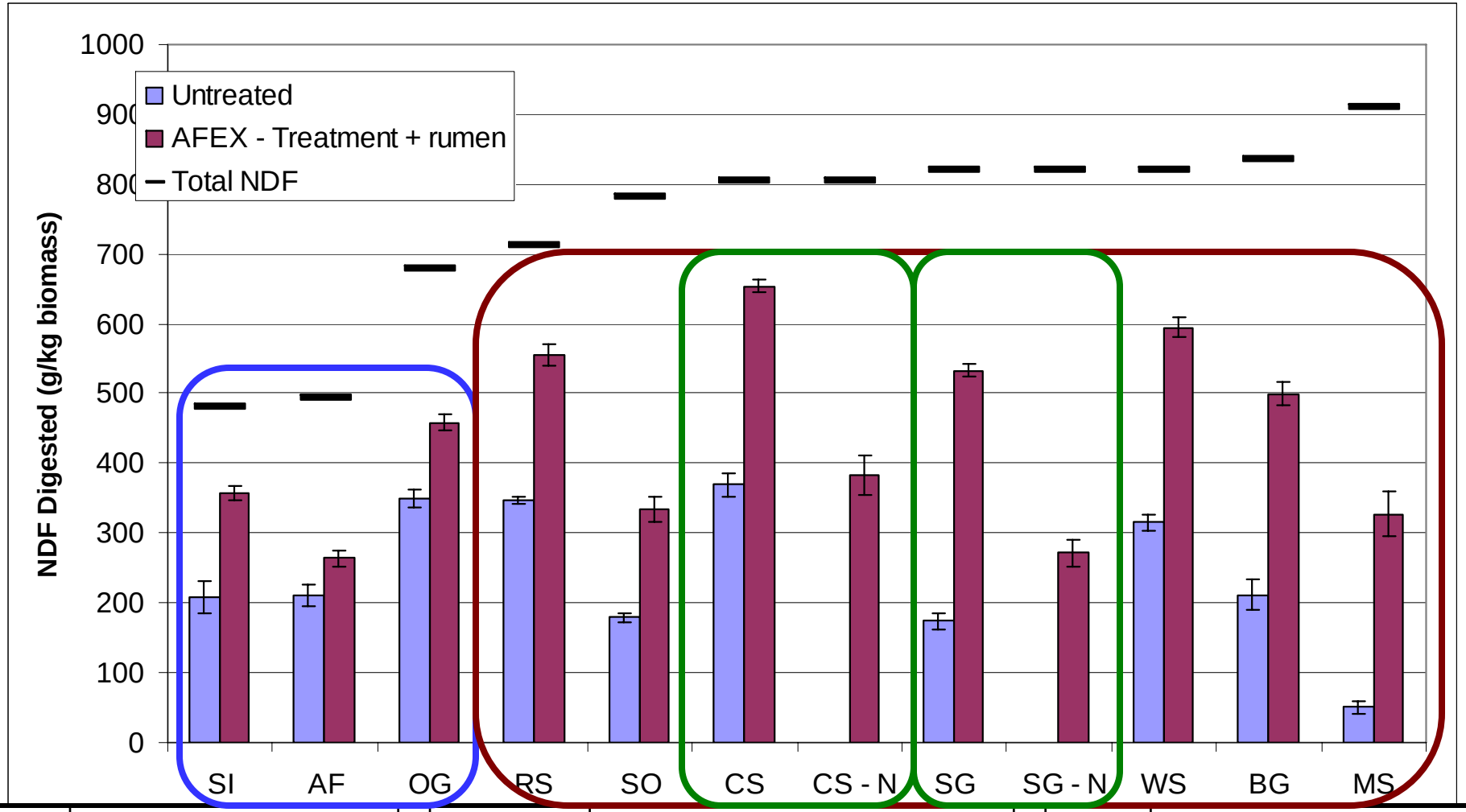
# Rumen and AFEX Digestion of NDF




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SI | Corn silage | | SO | Forage sorghum | | BG | Bagasse |
| AF | Alfalfa | | CS | Corn stover | | MS | Miscanthus |
| OG | Orchardgrass | | SG | Switchgrass | | | |
| RS | Rice Straw | | WS | Wheat straw | | -N | NH3 treated |

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# Total Digestible Nutrients and Net Energy available for Lactation

| | TDN | NEL | CP |
|---|---|---|---|
| | % DM | Mcal/lb | % DM |
| Corn grain | 88.7 | 0.91 | 9.4 |
| Corn silage | 68.8 | 0.66 | 8.8 |
| Orchardgrass hay | 63.1 | 0.62 | 18.1 |
| Alfalfa hay | 58.9 | 0.58 | 20.2 |
| AFEX Corn Stover | 75.6 | 0.79 | 17.2 |
| AFEX Switchgrass - late | 63.0 | 0.67 | 14.6 |

All values except AFEX materials obtained from *Nutrient Requirements of Dairy Cattle*, NRC 2001

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# Economics

| | NCSU | UWisc | Average |
|---|---|---|---|
| AFEX Corn Stover | $182 | $151 | **$167** |
| AFEX Switchgrass | $153 | $132 | $143 |
| Alfalfa Hay | $176 | $160 | **$168** |
| | | | |
| Corn Grain | | | $145 |
| Soybean Meal 48% | | | $320 |

- Expected corn stover production costs: $40-50/ton
  - **Increase value by over $100/ton**

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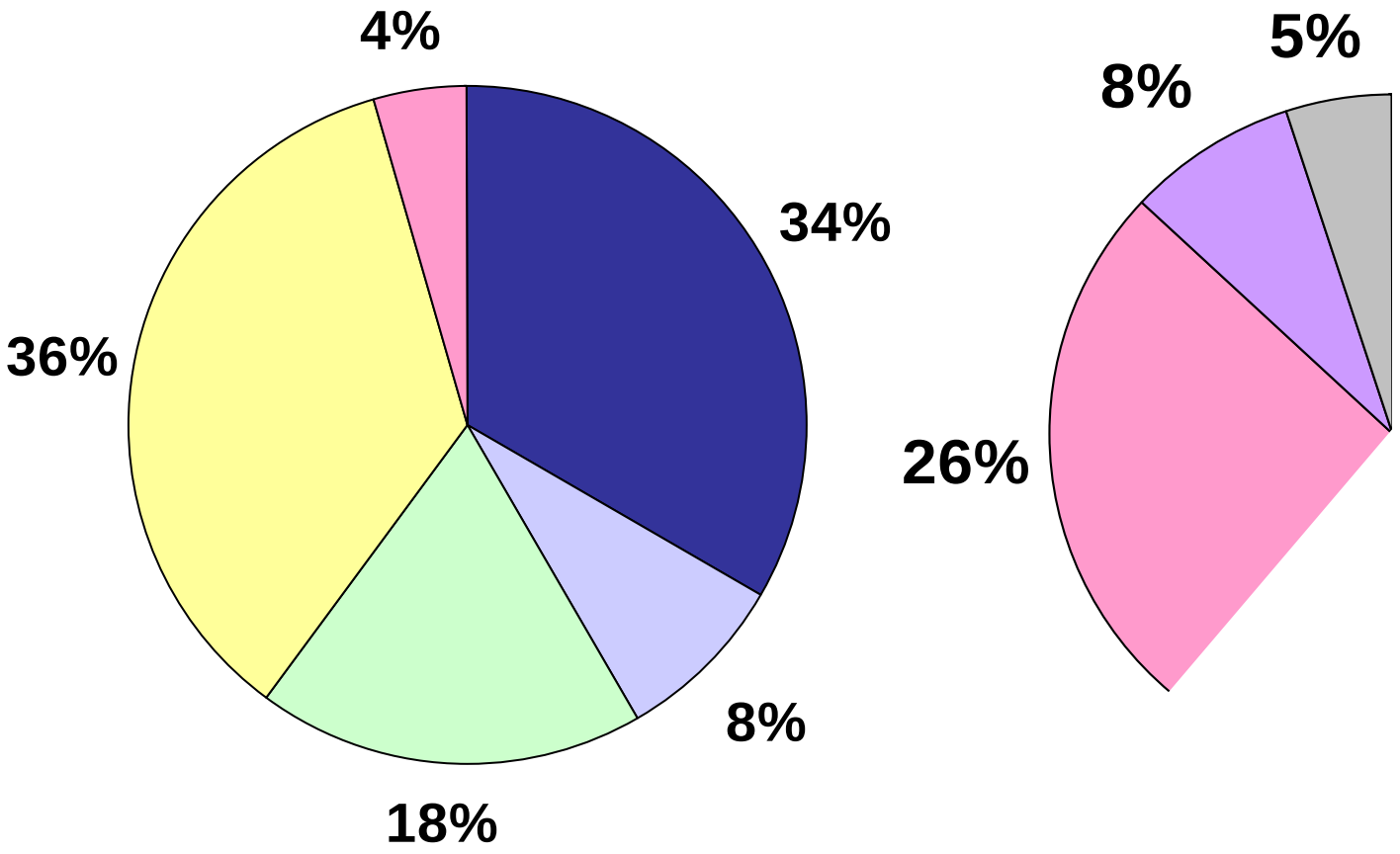
# Typical Animal Diets

Alfalfa Silage | Alfalfa Hay | Grain Silage | Corn Grain
Soybean Meal, 44% | Distiller's Grains | Other Protein Meal




**Broiler Chicken**

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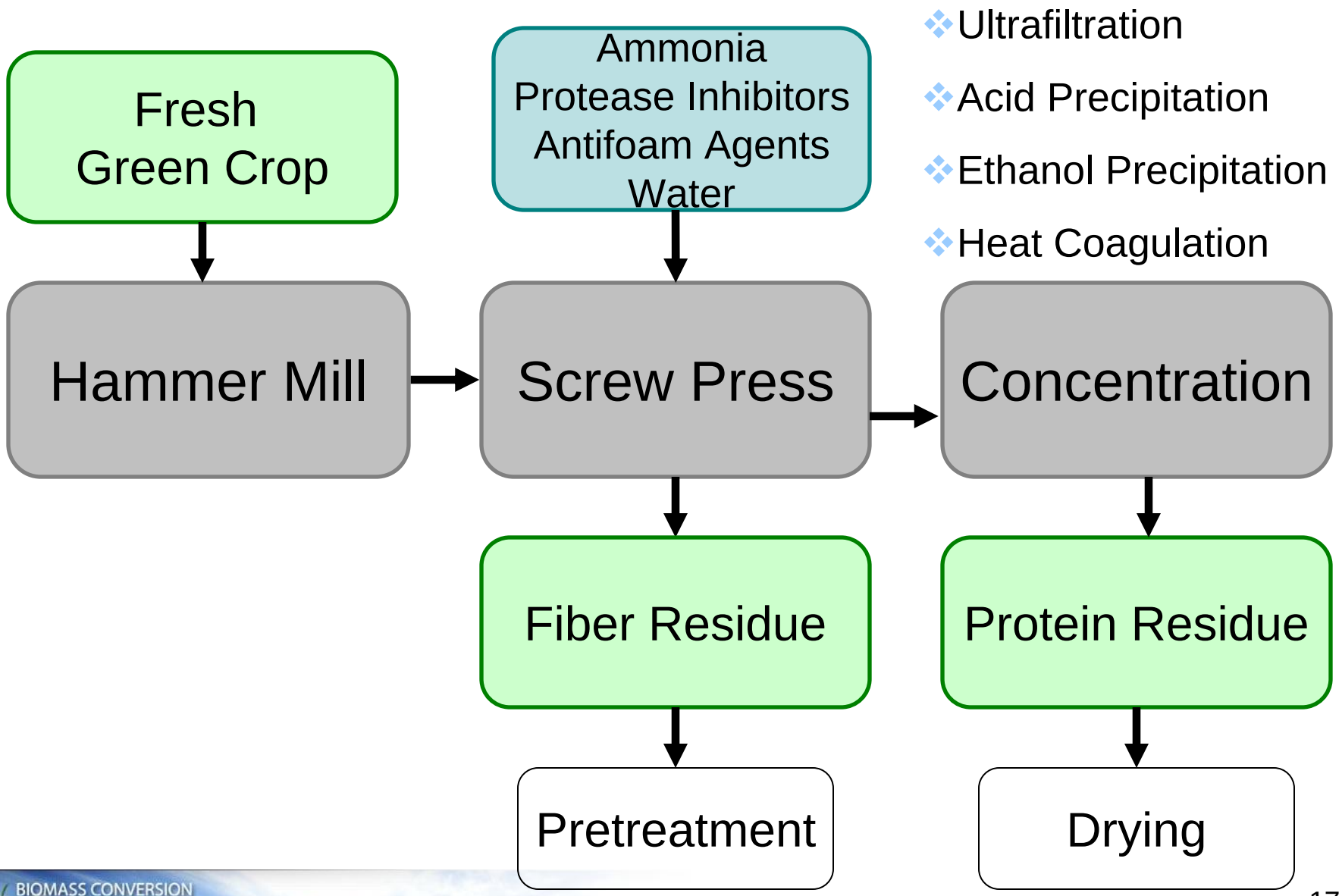
# Protein Extraction Method



# Essential Amino Acid Profile

| (% Total Protein) | SG | Soy* | Corn* |
|---|---|---|---|
| Arg | 2.1 | 7.5 | 2.9 |
| Thr | 4.9 | 4.3 | 3.1 |
| Val | 6.1 | 5.1 | 4.4 |

Leaf protein is a better complement to corn than soybeans!

*Allan, G. et al. **186** *Aquaculture, 293*-310 (2000)

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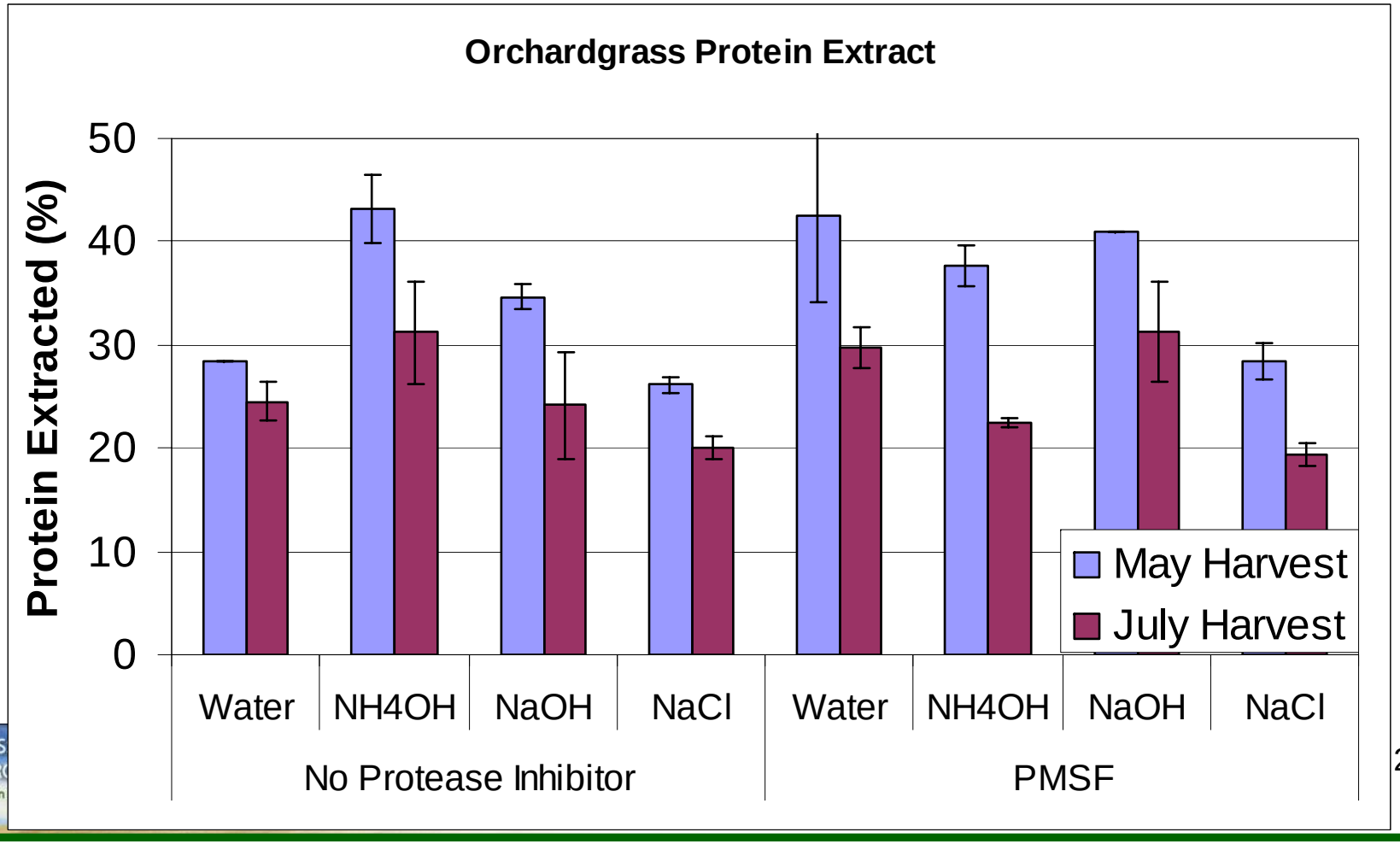
# Protein content in potential crops

| | Crude Protein |
|---|---|
| Mixed prairie grasses | up to 11.2% |
| Alamo Switchgrass – May | 7.5% |
| Cave-in-Rock Switchgrass – July | 4.3% |
| Orchardgrass – May | 29.4% |
| Orchardgrass - July | 21.8% |
| Alfalfa hay - Late | 10.2% |
| Crimson Clover cover crop* | 15.0% |
| Winter Rye cover crop* | 6.3% |
| Hairy Vetch cover crop* | 25.0% |

* - Results from University of California Sustainable Agriculture Research and Education Program Cover Crop Database

# Protein Extraction Yields

- Historical yields: 30-50% of all protein
  - Achievable with high liquid/solid ratio and washing
  - Low L/S ratio: requires pressing biomass



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# Effect of AFEX on protein extraction

- May or may not improve protein extraction yields
  - Reduced yields in switchgrass without the presence of a surfactant or reducing agent
  - Improved yields in orchardgrass
- Doubled the amount of polyphenolics in protein extract
  - Likely due to lignin breakages and solubilization
- Slightly decreased overall sugar yields
  - Eliminated by using whey as hydrolysate media

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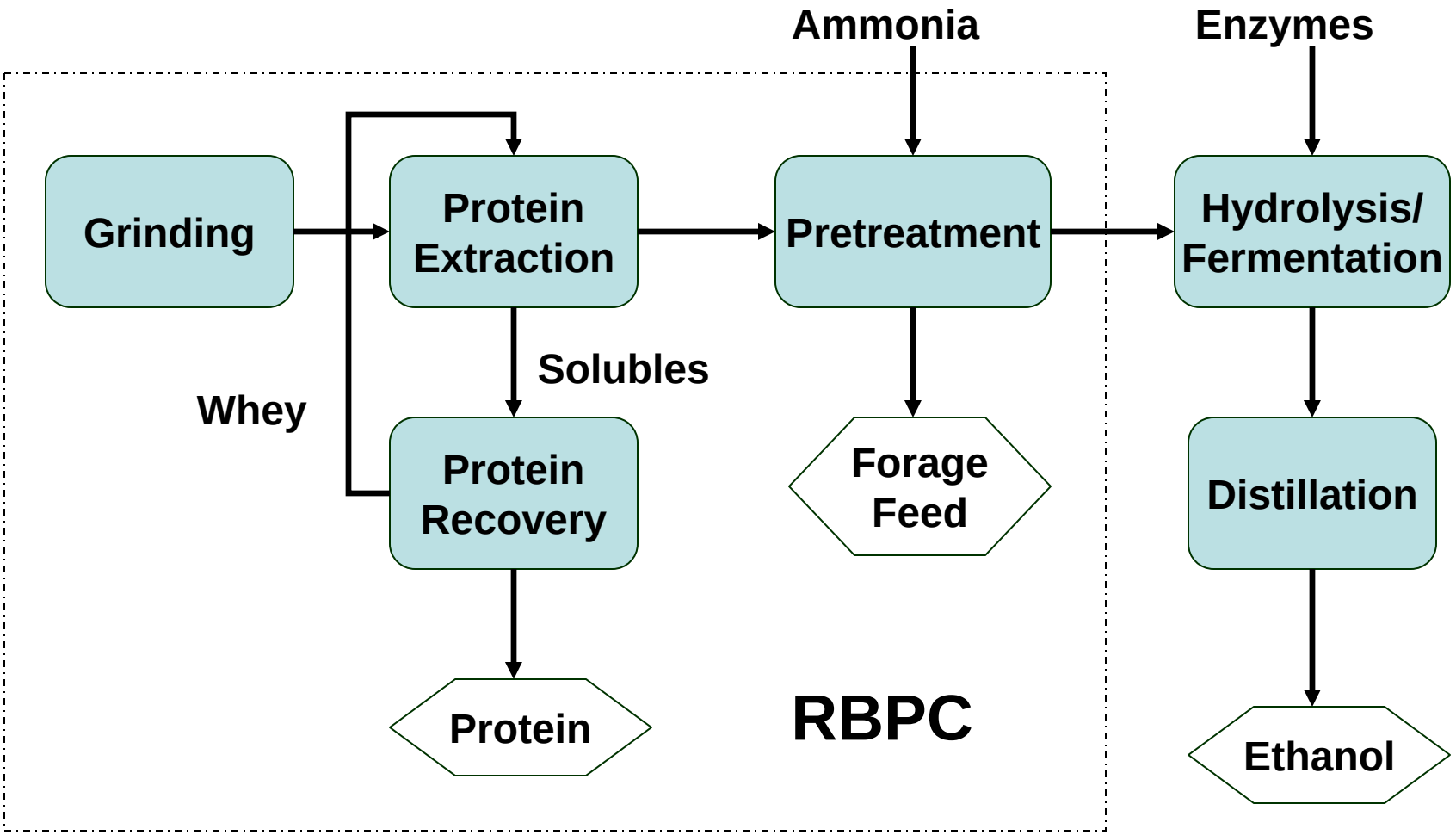
# Conclusions

- Solution to costs: co-production
  - Improved economies of scale due to size of ethanol production vs local feeding
  - Retains value of fiber for protein product
  - Lower feedstock cost – important as competition for land rises
- Benefits for cellulosic biofuels
  - Lowers the risk to production by opening separate markets
  - Eliminates “chicken and egg” argument and incentivizes farmers to grow energy crops
  - Reduces “Land use change” effect on CO2 production

# The Regional Biomass Processing Center (RBPC) Approach



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# Future Work

- Animal feeding trials on AFEX-treated forages
  - Actual response in weight gain and milk production
  - Toxicology studies
- Digestibility and economic evaluation of protein concentrates
- Full economic model of RBPC
  - With and without protein extraction
  - Variety of feedstocks tested

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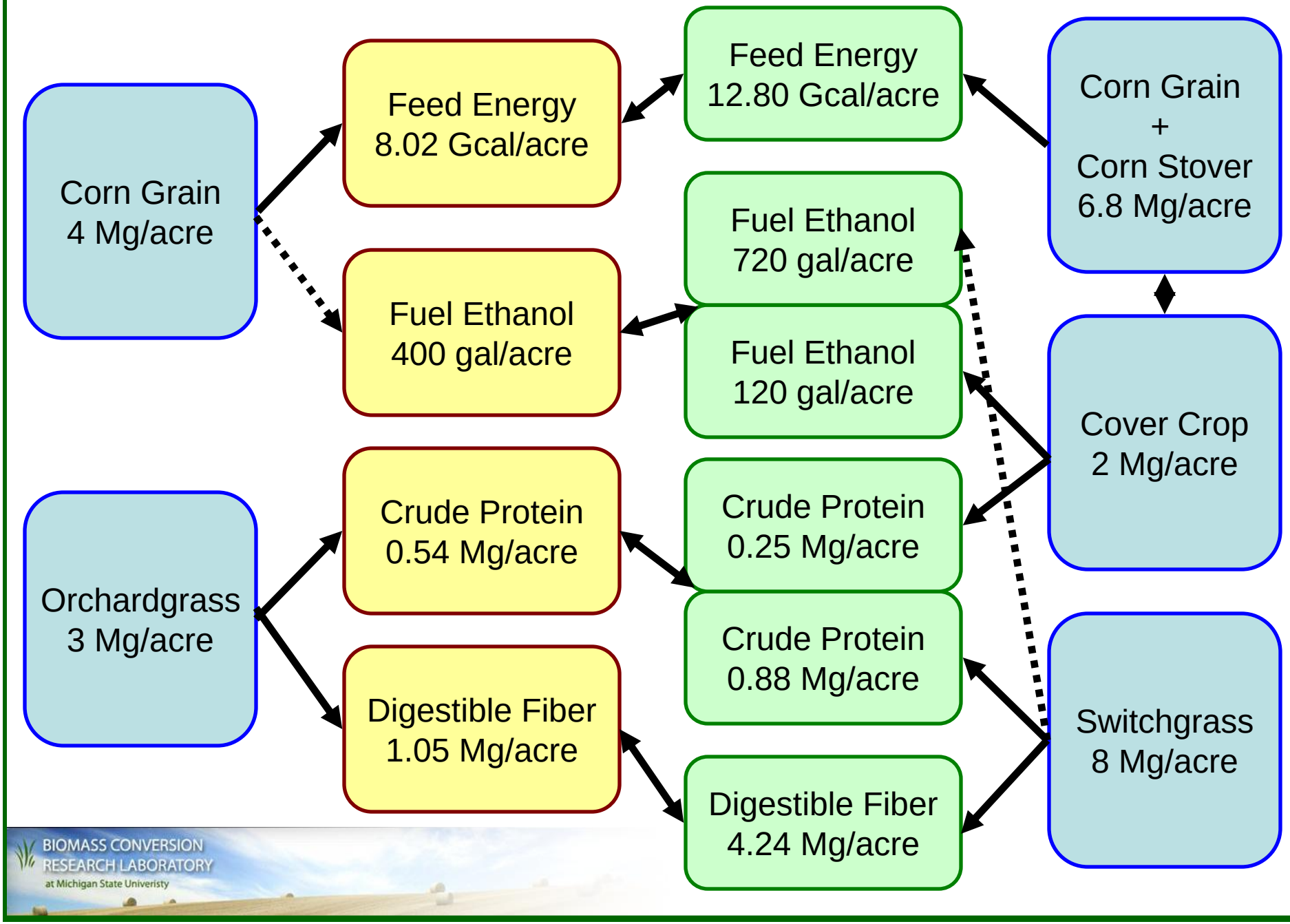
# Current Production vs Future Production

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at Michigan State Univeristy

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# Indirect Land Use Change?

- **50% less land** required for food production

| | | |
|---|---|---|
| 33 acres Orchardgrass<br>67 acres Corn grain | = | 8 acres Switchgrass<br>42 acres Corn + Cover crop |

- Average of 409 gal/acre over all land
  - Assuming remaining land is switchgrass
- Potential to replace **100% of US gasoline** with ethanol on current cropland while maintaining current food production
- *No indirect land use needed*... if we use our land efficiently

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# The BCRL Team