Treating Low Quality Forages to Improve Feeding Quality

or

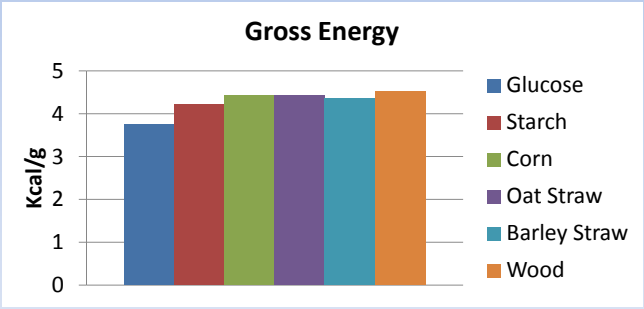
Feedstuff Alchemy

"How to turn straw into gold"

Montana Nutrition Conference
April 22, 2014
Tim Bodine, Ph.D., PAS

Why treat low quality forages?

- Gross energy is similar for many plants
- High lignin content impedes digestibility



History

- Chemical treatment started as early as 1880's
- Begun in paper-making
- Observed increased cellulose digestion

History-1920's

- NaOH
  - Soak for 18 h to 3 days
  - 2 tank system
  - High water requirement
  - Pollution
  - DM losses up to 20-25%
- Modifications improved feasibility
  - Combine NaOH and CaOH

Use of chemical treatment to enhance digestibility

NaOH:

- Jared and Donefer, 1970
- Hogan and Weston, 1971
- Saxena et al., 1971
- Anderson and Ralston, 1973
- Klopfenstein and Koers, 1973
- Rounds and Klopfenstein,1974
- Waller *and* Klopfenstein, 1975
- Todorov, 1975
- Garrett *et al.*,1976
- Rexen and Thomsen, 1976
- Chesson et al., 1981
- Wang et al. 2004

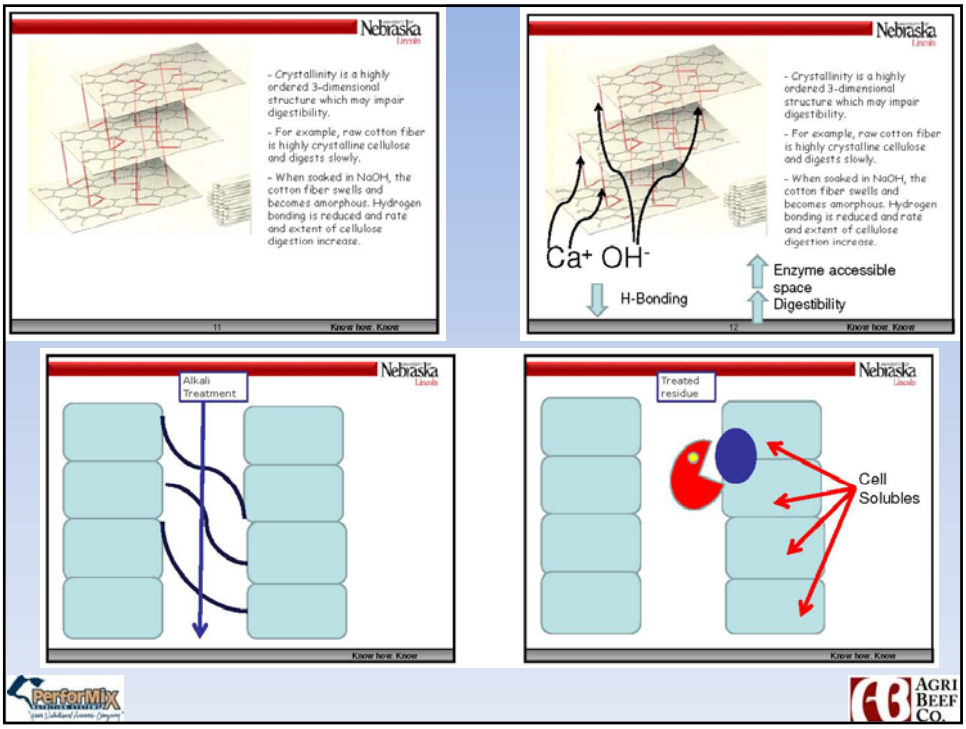
CaOH:

- Rounds and Klopfenstein,1974
- Waller and Klopfenstein, 1975
- Waller et al., 1976
- Leosing et al., 1980

Digestibility

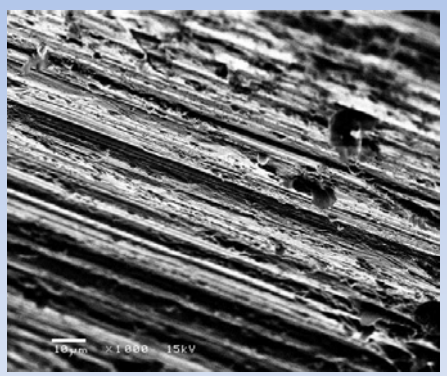
NaOH > CaO

NaOH+ CaO = ↑NaOH

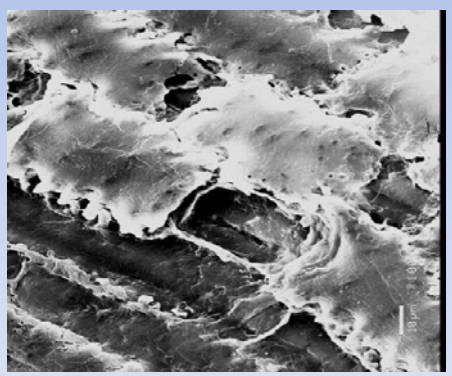


Electron Micrograph

Untreated



Treated



Courtesy MS Lime

History

- **Alkali**
- **Peroxides**
- **Ammonia**

History

- Hydrolytic
  - Sodium hydroxide
  - Calcium hydroxide
  - Potassium hydroxide
  - Ammonium hydroxide
  - Anhydrous Ammonia
  - Urea

History

- Hydrolytic
  - Partial solubilization of hemicellulose
  - > 5% NaOH some solubilization of lignin & silica
  - Disruption of intermolecular hydrogen bonding of cellulose
  - Increased rate of fiber hydration
  - Increased rate of bacterial colonization
  - Decreased lag time

– Van Soest, Berger

Alkali treatment processes

- NaOH
- NaOH + CaO
- CaO
- CaOH

History

- Alkali
- Peroxides
- Ammonia

History

- Oxidative
  - Hydrogen peroxide
  - Ozone
  - Sulfur dioxide
  - Sodium chlorite
  - Peracetic acid

History

- Oxidative
  - Reduction in cell wall lignin
  - Cleavage of glycosidic linkages of cell wall polysaccharides
  - Increase in soluble carbohydrate concentration
  - Usually more effective in monocots than dicots

– Van Soest, Berger

History

- Alkali
- Peroxides
- Ammonia

Treatment processes

- Anhydrous
  - DM intake increased 22% over 21 studies
  - Digestibility 15% average increase in 32 studies
  - Retain ~ 33% of NH3
  - Temperature, water content, length of reaction time impacts results

Alkali treatment processes

- NaOH
  - DM intake increased 22% in 24 study summary
  - Digestibility 30% average increase in 32 studies
  - All diets >60% treated residue

Alkali treatment processes

- NaOH
  - Cost of chemical
  - Sodium level in manure
  - Chemical handling safety concerns
  - Length of reaction time
  - Storage
  - Feasibility
  - Use in finishing diets?

Alkali treatment processes

- Advantage of lime over NaOH & Ammonia
  - Cost (Chemical $20-30/ton of treated feed)
  - Safety (less caustic than NaOH)
  - Environment (Ca less soil impact than Na)

Alkali treatment processes

- CaO
  - Less caustic than other chemicals
  - Cost competitive
  - Improvement of digestibility
  - No detrimental impact of Ca on fields
  - Dietary Ca is needed
  - CaOH should work, less heat, need more

Alkali treatment processes

- $CaO + H_2O$
  - $CaO + H_2O = Ca(OH)_2$
  - If mix two parts water and one part lime
    - Solution will boil!
  - Thermochemical reaction
    - Breaking bonds releasing heat
  - Release of heat
    - That means it will cause fires!

Use of "lime" to improve digestibility

Forms of "lime"

$CaCO_3$ + (heat) ⟹ CaO

Limestone — Quick lime

CaO + H2O ⟹ Ca(OH)2

Quick lime — Slaked or hydrated lime

Schroeder, NDSU, 2012

Growing Cattle

Growing Cattle

Dry matter and nutrient composition of diets fed to growing steers[1]

	Corn Stover		Wheat Straw	
Ingredient, %DM	**Treated**	**Untreated**	**Treated**	**Untreated**
Treated residue	**69.0**	**--**	**69.0**	**--**
Untreated residue	**--**	**67.0**	**--**	**67.0**
WDGS	**30**	**30**	**30**	**30**
Supplement	**1.0**	**1.42**	**1.0**	**1.42**
Limestone		**1.58**		**1.58**

[1]Adapted from Shreck et al., 2014

Growing Cattle

Effect of crop residue and alkaline treatment on growing steer performance[1]

	Corn Stover		Wheat Straw	
Item	Treated	Untreated	Treated	Untreated
Initial BW, lb	729	729	728	727
Ending BW, lb	844[b]	834[c]	868[a]	841[b]
DMI, lb/day	16.7	15.7	18.7	16.4
ADG, lb	1.67[b]	1.52[c]	2.02[a]	1.63[bc]
F:G	10.0	10.32	9.25	10.06
$ Profit/head[2]	-15.0	0.0	-6.8	0.00

[1] Adapted from Shreck et al., 2014
[2] Relative to untreated crop residue of the same type

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Growing Cattle

- Growing calves in back-grounding feedlot
- Cow-calf pairs fed in confinement during winter
- Bull developer rations to prepare for breeding
- Bull developer rations to prepare for sale

In the feedbunk-Finisher

Nebraska Finishing

Treatment diets					
		Wheat straw		Corn stover	
Ingredient, %	Control	Treated	Untreated	Treated	untreated
Rolled Corn	46	36	36	36	36
Stover treated				20	
Straw, treated		20			20
Straw untreated	3		20		
Stover untreated	3				
Cobs untreated	3				
WDGS	40	40	40	40	40
Supplement	4	4	4	4	4
Adapted from Shreck et. al, 2012					

Nebraska Finishing

Performance and Carcass Characteristics. N= 336					
		Wheat straw		Corn stover	
	Control	Treated	Untreated	Treated	Untreated
Initial BW, lb	785	790	782	791	780
Final BW, lb	1313	1350	1278	1325	1267
ADG, lb	3.78	4.01	3.55	3.83	3.49
DMI, lb	25.8	25.8	25.2	26.1	25.06
F:G, lb	6.83	6.44	7.12	6.82	7.18
Profit $3.00 corn	0	17.37	-10.28	-0.05	-13.32
Profit $4.50 corn	0	35.8	-2.08	13.68	-6.70
Profit $6.00 corn	0	54.1	6.04	27.33	-0.16
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Finishing Cattle

Table 3. DM, Ash, ADF and NDF for different samples of CaO treated corn stover					
Stover Batch	Ca, %	DM, %	Ash, %	ADF, %	NDF, %
Corn stover, pre treatment[1]	0.34	89.75	8.44	47.6	71.9
Bagged Treated stover #1[1]	3.35	51.7	25.1	45.63	54.55
Bagged Treated stover #2[1]	3.9	50.1	21.0	42.6	52.8
Treated stover, load #2[2]	-	51.4	17.5	-	-
Treated stover, load #4[2]	-	53.6	19.4	-	-
Treated stover, load #6[2]	-	39.2	27.1	-	-
Treated stover, load #8[2]	-	50.2	15.9	-	-

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Finishing Cattle

Table 1. Treatment diets [1]

	Treatment Diets (DM Basis).	
Ingredient, %	Control, ML #4	Treated Stover
Dry Distillers Grain	13.1	13.1
Wheat-Rolled	20.0	20.0
Corn- Dry Rolled	18.1	14.1
Corn Syrup	1.1	1.1
Corn HM	15.8	15.8
French Fries	5.0	5.0
Slurry	9.2	9.2
Mixed Hay	9.9	5.9
Tallow	3.7	3.7
Finish Supplement	3.8	3.8

Finishing Cattle

Table 1. Treatment diets		
Treated Stover	Treatment Diets (DM Basis).	
Nutrients	Control, ML #4	Treated Stover
CP	13.8	13.6
Fat, %	8.1	7.3
Ca, %	.65	1.03
P, %	.36	.36
Ash, %	5.4	7.2
ADF, %	11.1	11.5
NDF, %	18.4	18.5
NEg, Mcal/Lb-Owens	0.64	0.60
NEm, Mcal/Lb-Owens	0.94	0.90
NEg, Mcal/Lb-Galyean	0.58	0.54
NEm, Mcal/Lb-Galyean	0.87	0.82

Finishing Cattle

Table 2. Performance of steers fed a finishing diet either without or with calcium oxide treated corn stover				
item	Control	CaO Treated	S E	P-value
Initial body weight, LB	860.2	860.0	35.3	0.99
Reimplant weight, LB	1024.6	1022.5	43.3	0.92
Final body weight, LB	1389	1353	21.5	0.25
Dry matter intake, LB	25.25	25.1	1.28	0.77
Total gain, LB	523.4	479.3	31.4	0.049
Average daily gain, LB	3.92	3.56	0.11	0.035
Feed:Gain, LB	6.48	7.1	0.15	0.008
Feed only Cost of gain difference, per CWT	---	$7.10	2.7	0.079

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Finishing Cattle

Table 2. Carcass characteristics for steers fed a finishing diet either without or with calcium oxide treated corn stover

item	Control	CaO Treated	S E	P-value
Grade, %				
Prime	2.2	0.76	0.39	0.018
Choice	90.66	85.87	2.54	0.026
Select	7.05	13.44	2.32	0.001
Dressing percentage	62.7	62.1	0.166	0.03
Yield grade, %				
YG1	6.18	11.7	2.63	0.008
YG2	44.5	55.06	5.05	0.003
YG3	39.06	28.89	5.79	0.006
YG4	6.9	1.25	2.17	0.01

The Process (StoverCal)

Lime: Safety Considerations

- **Respiratory Protection**
  - **Dust masks recommended for comfort and/or protection**
- **Protective Gloves**
  - **Cloth or leather gloves**
- **Reduce wrist burns from sweat by using protective cream**

Source: Mississippi Lime MSDS for Calcium Oxide

Lime: Safety Considerations

- Eye Protection
  - ALWAYS wear safety glasses and/or goggles. Flush eyes immediately and seek medical attention. Contact lenses may impede first aid.
- Other Protective Clothing
  - Wear long sleeve shirts and pants to minimize contact w/lime

Source: Mississippi Lime MSDS for Calcium Oxide

Safety issues with Quicklime (CaO)

- If making slurry:
  - add quicklime
  - large volume of water
  - do it slowly
  - avoid boiling and/or rupture of containers

Safety issues with Quicklime (CaO)

- Store quicklime in dry locations.
  - Worker safety:
    - Quicklime dust will cause severe irritation or burning of eyes, skin, respiratory and GI tract
    - Dust will react with perspiration on skin.
  - Do not inhale dust.
  - Eye protection needed/do not wear contact lenses
  - Wash with soap and water to remove dust.

Recipe

Ingredient	Dry Matter Amount, lb	As Fed amount (90 % DM)
Stover or Straw	950	1055 (950 DM + 194 H_20)
Lime (CaO)	50	50
Water	1000	895 (~ 102 Gallons)
Total	2000	2000

The Process (Nebraska)

- Supplies
  - Corn Stover or Wheat straw
    - Nutrient analysis is very helpful for calculating DM
  - CaO or CaOH
    - Quicklime (CaO) or slacked lime ($Ca(OH)_2$)
    - CaOH is less reactive but requires more (6.25% vs. 5.0%)
  - Water
    - Need to be able to add large amounts quickly

Step 1: Grinding

- Ground to pass through a 3 inch screen

Lubbe and Shreck, 2012

Step 2: Add CaO

- Add CaO at 5% wt/wt (DM basis) of forage

Lubbe and Shreck, 2012

Step 3: Add Water

- Add water until mixture reaches ~ 50% DM

Lubbe and Shreck, 2012

Step 4: Mix

- Mix, add water to hot spots, unload

Step 5: Store

- 5-7 days minimum
- Pile or bag
- Store 10-14 days, pack for up to 6 months

Sources

- http://www.stovercal.com/index.html
- http://www.stovercal.com/Corn-Stover-Treatment.html

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QUESTIONS?

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