Alkaline Treatment of Residue

Matt Luebbe and Adam Shreck

Know how. Know now.

Introduction

- Energy costs
- Alternative resources
- Availability of residues
  - Corn
  - Wheat
  - Soybean stubble

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Replacing corn

- WDGS
  - ~130% value of corn @ 40% diet DM (Bremer et al., 2010)
- Roughage
  - Decreased performance (Bartle et al., 1994)
  - Higher cost per unit energy
- Feeding treated roughage with WDGS
  - Limited research
  - NE, IA, IL

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History

- Chemical treatment began in 1880's
  - Started with paper making
  - Observation of increased cellulose digestibility
- Alkali
- Peroxides
- Ammonia

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Beckman Method

- 1920's
- NaOH
- Soak residue for 18 h to 3 days
- 2 tank system
- High water requirement
- Pollution
- DM losses 20-25%
- Modifications improved feasibility
  - Combining NaOH and CaOH

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Hydrolytic	Oxidative
1. Sodium Hydroxide	1. Hydrogen Peroxide
2. Calcium Hydroxide	2. Ozone
3. Potassium Hydroxide	3. Sulfur Dioxide
4. Ammonium Hydroxide	4. Sodium Chlorite
5. Anhydrous Ammonia	5. Peracetic Acid
6. Urea	

GOAL disrupt polysaccharide-lignin associations

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Hydrolytic

- 1. Partial solubilization of hemicellulose
- 2. Above 5% NaOH some lignin and silica solubilized
- 3. Disruption of intermolecular hydrogen bonding of cellulose
- 4. Increased rate of fiber hydration
- 5. Increased rate of bacterial colonization
- 6. Decreased lag time

Van Soest, Berger

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Oxidative

- 1. Reduction in cell wall lignin
- 2. Cleave glycosidic linkages of cell wall polysaccarides
- 3. Increase in soluble carbohydrate concentration
- 4. Usually more effective with dicots than monocots

Van Soest, Berger

Know how. Know now.

Goal: Increase pH

- pH needs to be above 8
- Fermentation is not desired
  - Acidifying process making treatment less effective
- Combination with ethanol byproducts for storage
  - DGS pH 3.0-3.5
- Storage vs ensiling

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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

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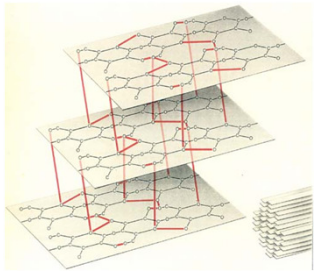

- Crystallinity is a highly ordered 3-dimensional structure which may impair digestibility.
- For example, raw cotton fiber is highly crystalline cellulose and digests slowly.
- When soaked in NaOH, the cotton fiber swells and becomes amorphous. Hydrogen bonding is reduced and rate and extent of cellulose digestion increase.

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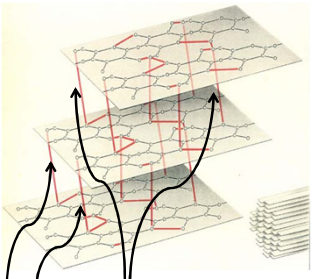

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Ca^{+} OH^{-}

H-Bonding

Enzyme accessible space

Digestibility

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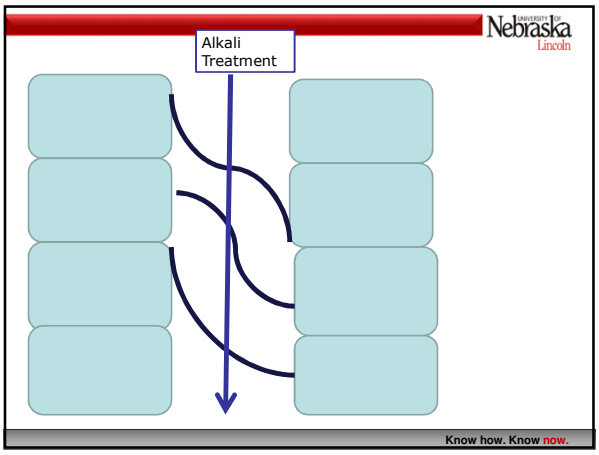

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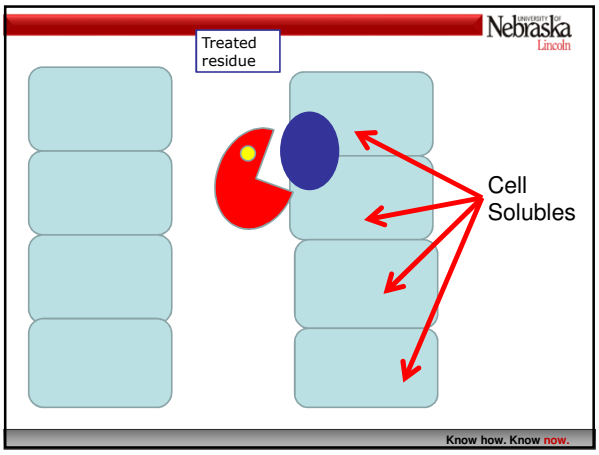

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Berger 2012 Review

NaOH

- 1. DM intake increased 22% when summarized 24 studies
- 2. Averaged over 32 studies, DM digestibility increased 30%
- 3. All diets > 60% treated residue

Anhydrous

- 1. DM intake increased 22% averaged over 21 treated crop residues
- 2. DM digestibility increased 15% averaged over 32 studies
- 3. Usually ~ 33% of the NH_3 is retained.
- 4. Temperature, water content, length of reaction time influences effectiveness

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Challenges

NaOH

- Cost of chemicals
- Na in manure
- Safety-handling
- Length of reaction time
- Storage
- Feasibility
- What about inclusion in finishing diets?

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Current

CaO

- Quicklime
- Less caustic than other treatments
- Cost competitive
- Improvement of digestibility
- No detrimental impacts on fields receiving manure
- Need the dietary calcium anyway
- CaOH should work similar, but less heat, and need slightly more

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$CaO + H_2O$

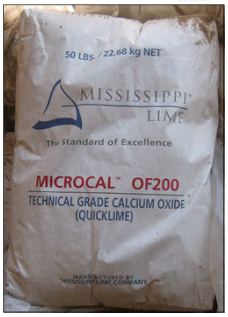
Release of heat

2 parts water +1 part lime

Solution will boil

Thermochemical

Heat + releasing bonds



$CaO\ (s) + H_2O \rightleftharpoons (l)\ Ca(OH)_2\ (aq)$

Know how. Know now.

Shreck et al., 2011

- Optimize use of chemical treatments
- Factors:
  - DM
  - Chemical
  - Reaction Length
  - Ambient Temperature
  - Forage type

} Effects on Digestibility *In Vitro*

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Summary of *in vitro* work

- Chemical treatment, relative to control:
  - 3%CaO 2%NaOH: 15% unit increase in DMD
  - 4%CaO 1%NaOH: 14% unit increase in DMD
  - 5% CaO: 11% unit increase in DMD
- DM:
  - 35%: 1.25% reduction
  - 50%: optimum
- Temperature, relative to room temp (30°C)
  - 40°C: 1% unit increase
- 7 d treatment

Shreck, 2011

Know how. Know now.

Treating Stover-Step 1.

- **Ground (*Mighty Giant, Jones Mfg, Beemer, NE*)**
  - 3-in screen

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Treating Stover-Step 2.

- CaO added at 5% (DM-basis) of forage

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Treating Stover-Step 3.

- Granular CaO
- Standard quicklime (1/4")
- >98% purity
- 71% Ca
- $350/ton

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Treating Stover-Step 4.

- Water added to equal 50% DM

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Treating Stover-Step 5.

- Bagged and stored for at least one week prior to feeding

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Diets

Ingredient, % of DM	Control	Wheat Straw		Corn Stover	
DRC	46.0	36.0	36.0	36.0	36.0
WDGS	40.0	40.0	40.0	40.0	40.0
Straw-treated	—	20.0	—	—	—
Stover-treated	—	—	—	20.0	—
Cobs-native[1]	3.3	—	—	—	—
Wheat straw-native	3.3	—	20.0	—	—
Corn stover-native	3.3	—	—	—	20.0
Supplement[2]	4.0	4.0	4.0	4.0	4.0

[1] 20% cobs treated and native (data not shown)
[2] Balanced for Ca:P

336 short yearlings- 778 lb
6 pens/trt

10% units replacement

Know how. Know now.

Carcass-adjusted performance

		Wheat Straw		Corn Stover		
Item	Control	Treated	Native	Treated	Native	F-test
ADG, lb	3.78^{abc}	4.01^{a}	3.55^{cd}	3.83^{ab}	3.49^{d}	<0.01
DMI, lb	25.8	25.8	25.3	26.1	25.1	0.30
F:G	6.83^{ab}	6.44^{a}	7.12^{b}	6.82^{a}	7.18^{b}	0.06

^{abcd}Within a row, values lacking common superscripts, differ (P<0.05)

140 DOF: May-Oct

10% units replacement

Know how. Know now.

		Wheat Straw		Corn Stover		
Item	Control	Treated	Native	Treated	Native	F-test
HCW	834^{bc}	857^{a}	811^{cd}	841^{ab}	805^{d}	<0.01
12th rib fat	0.53^{a}	0.50^{ab}	0.44^{c}	0.53^{a}	0.44^{c}	0.30
Marbling[1]	517	508	484	501	494	0.06

[1]500=Small, 600=Modest

^{abcd}Within a row, values lacking common superscripts, differ (P<0.05)

Know how. Know now.

Table 1. Dietary treatments Exp 1101

		1" Grindsize		3"Grindsize	
Ingredient, % of DM	Control	Treated	Untreated	Treated	Untreated
HMC	25.5	18.0	18.0	18.0	18.0
DRC	25.5	18.0	18.0	18.0	18.0
Stover-treated[1]	—	20.0	—	20.0	—
Stover-not treated	5.0	—	20.0	—	20.0
MDGS	40.0	40.0	40.0	40.0	40.0
Supplement[2]	4.0	4.0	4.0	4.0	4.0

[1]Treated with 5% CaO and water added to 50% DM'

[2]Formulated to provide 360 mg/hd/d Rumensin and 90 mg/hd/d Tylan

360 calf-feds- 822 lb
6 pens/trt

15% units replacement

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		1"Grindsize		3" Grindsize		
Item	Control	Treated	Untreated	Treated	Untreated	F-test
ADG, lb	3.67^{a}	3.73^{a}	3.28^{b}	3.58^{a}	3.21^{b}	<0.01
DMI, lb	24.0^{abc}	23.6^{bc}	24.5^{ab}	23.5^{c}	24.8^{a}	0.04
F:G	6.54^{ab}	6.32^{a}	7.47^{c}	6.55^{b}	7.72^{b}	<0.01

^{abcd}Within a row, values lacking common superscripts, differ (P<0.05)

15% units replacement

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Item	Control	1"Grindsize Treated	1"Grindsize Untreated	3" Grindsize Treated	3" Grindsize Untreated	F-test
HCW	868[a]	873[a]	831[b]	858[a]	825[b]	<0.01
12th rib fat	0.57	0.55	0.51	0.56	0.52	0.24
Marbling[1]	595	568	546	590	579	0.11

[1]500=Small, 600=Modest

[abcd]Within a row, values lacking common superscripts, differ (P<0.05)

15% units replacement

Know how. Know now.

Calf-feds and yearlings

Ingredient, % of DM	Control	3"Grindsize Treated	3"Grindsize Untreated
HMC	25.5	18.0	18.0
DRC	25.5	18.0	18.0
Stover-treated[1]	—	20.0	—
Stover-not treated	5.0	—	20.0
MDGS	40.0	40.0	40.0
Supplement[2]	4.0	4.0	4.0

[1]Treated with 5% CaO and water added to 50% DM'

[2]Formulated to provide 360 mg/hd/d Rumensin and 90 mg/hd/d Tylan

15% units replacement

Know how. Know now.

Carcass-adjusted performance-Calf feds

•Calf-feds (n=192) fed from Nov-May, 8 pens/trt

Item	Control	Corn Stover Treated	Corn Stover Native	F-test
DMI, lb/d	22.4	22.4	22.9	0.42
ADG, lb	3.67[a]	3.61[a]	3.24[b]	<0.01
F:G	6.36[a]	6.22[a]	7.05[b]	<0.01

[abcd]Within a row, values lacking common superscripts, differ (P<0.05)

15% units replacement

Johnson et al., 2013 NE Beef report

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Carcass-adjusted performance-Calf feds

•Calf-feds (n=192) fed from Nov-May, 8 pens/trt

Item	Control	Corn Stover Treated	Corn Stover Native	F-test
Live BW	1361[a]	1346[a]	1311[b]	<0.01
HCW	860[a]	860[a]	812[b]	<0.01
Dressing, %	63.3[a]	63.6[a]	62.0[b]	<0.01
12th rib fat	0.51	0.41	0.48	0.07
Marbling[1]	582[a]	551[a]	532[b]	<0.01

[1]500=Small, 600=Modest

[abcd]Within a row, values lacking common superscripts, differ (P<0.05)

15% units replacement

Johnson et al., 2013 NE Beef report

Know how. Know now.

Carcass-adjusted performance-Yearlings

•Yearlings (n=192) fed from June-Oct, 8 pens/trt

Item	Control	Corn Stover Treated	Corn Stover Native	F-test
DMI, lb/d	26.8[a]	27.6[a]	28.8[b]	<0.01
ADG, lb	4.18[a]	4.04[a]	3.77[b]	<0.01
F:G	6.42[a]	6.85[c]	7.65[b]	<0.01

[abcd]Within a row, values lacking common superscripts, differ (P<0.05)

15% units replacement

Johnson et al., 2013 NE Beef report

Know how. Know now.

Carcass-adjusted performance-Yearlings

•Yearlings (n=192) fed from June-Oct, 8 pens/trt

Item	Control	Corn Stover Treated	Corn Stover Native	F-test
Live BW	1457	1447	1441	0.09
HCW	914[a]	901[b]	878[b]	<0.01
Dressing, %	62.8[a]	61.3[c]	60.9[b]	<0.01
12th rib fat	0.59	0.57	0.53	0.16
Marbling[1]	574	556	537	0.09

[1]500=Small, 600=Modest

[abcd]Within a row, values lacking common superscripts, differ (P<0.05)

15% units replacement

Johnson et al., 2013 NE Beef report

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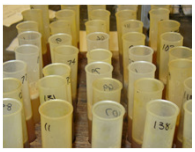
Quality control

- Best to have original (untreated) sampled
- Measurements
  1. DM (water only)
  2. Chemical (Ca)
  3. Amount of NDF solubilized
  4. pH
  5. *In vitro* digestibility
- Lab energy calculation can be incorrect



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Exp	NDF, % Untreated	NDF, % Treated	% unit	% change
Summer-2010				
Straw	88.5	69.9	18.6	21.0
Stover	87.8	74.7	13.1	15.0
Winter-2011				
Stover	77.9	65.8	12.1	18.1
Summer-2011				
Straw	82.9	71.6	11.3	13.6
Stover	82.2	71.0	11.2	13.7

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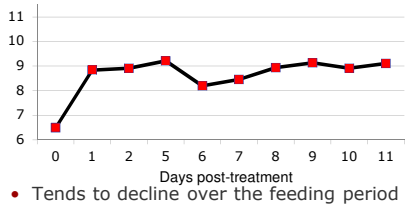
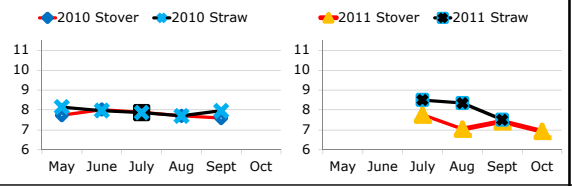
pH



- Tends to decline over the feeding period



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Energy value of treated residue

Item	OM Digestibility Untreated	OM Digestibility 5% CaO	% Increase
In vitro			
Straw	27.9	43.0	68.4
Stover	24.3	34.9	51.7
In vivo, 25% inclusion			
Straw	69.3	78.4	52.4
Stover	66.3	78.4	73.2

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Energy value of treated residue

Item	OM Digestibility Untreated	OM Digestibility 5% CaO	% Increase
In vitro			
Straw	27.9	43.0	68.4
Stover	24.3	34.9	51.7
In vivo, 25% inclusion			
Straw	69.3	78.4	52.4
Stover	66.3	78.4	73.2

Item	TDN Untreated	% Increase	TDN
In vitro			
Straw	41	1.68	**69.0**
Stover	41	1.51	**62.0**
In vivo, 25% inclusion (DM basis)			
Straw	41	1.52	**62.5**
Stover	41	1.73	**71.0**

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Energy value-Relative to corn

- NRC (1996) using performance of control
  - NE_M and NE_g adjusters
- Assume:
  - MDGS: 112 TDN (125% energy value of corn)
  - WDGS: 118 TDN (130% energy value of corn)
  - Corn stover/wheat straw 41 TDN
  - Book values for corn

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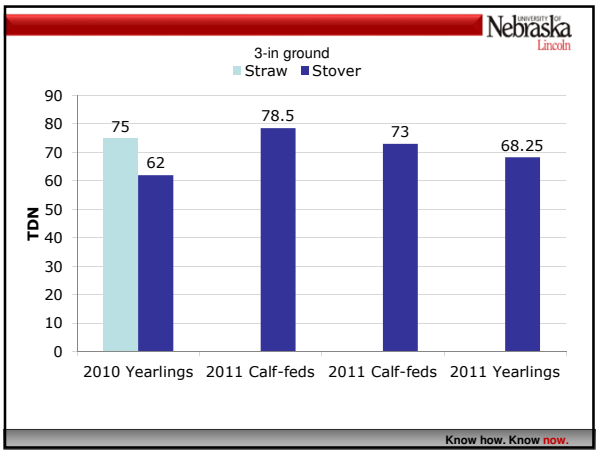
Nebraska Lincoln
3-in ground
Straw Stover
TDN
90
80
70
60
50
40
30
20
10
0
75
62
78.5
73
68.25
2010 Yearlings
2011 Calf-feds
2011 Calf-feds
2011 Yearlings
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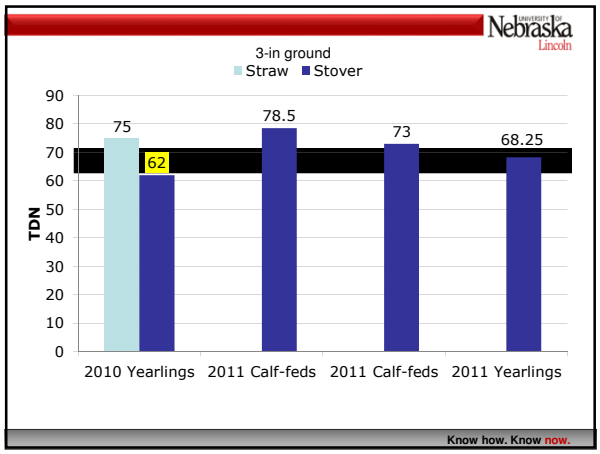
Nebraska Lincoln
3-in ground
Straw Stover
TDN
90
80
70
60
50
40
30
20
10
0
75
62
78.5
73
68.25
2010 Yearlings
2011 Calf-feds
2011 Calf-feds
2011 Yearlings
Know how. Know now.


Nebraska Lincoln
Summary
Including 20% treated stalks/straw with 40% wet/modified DG:
Similar performance
Similar carcass
Lower diet cost
We have future plans, need funding
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