Forage Quality: Fiber Digestibility

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ROCK RIVER LABORATORY, INC
AGRICULTURAL ANALYSIS

Forage Quality

Preserving feed

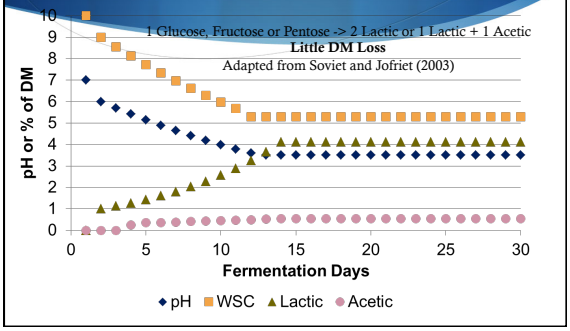
Secondary Aim?

Where does Shrink happen?

Winning Fermentation

- **How do we preserve all 100 tons?**
- Grow the **right** bacteria, **quickly**
  - Convert only optimal amount of carbs into acid
- Produce effective acid amount in fastest possible time
- Avoid secondary fermentation
  - At all costs…

Ideal process – Goal



Dynamic Forage Fermentation

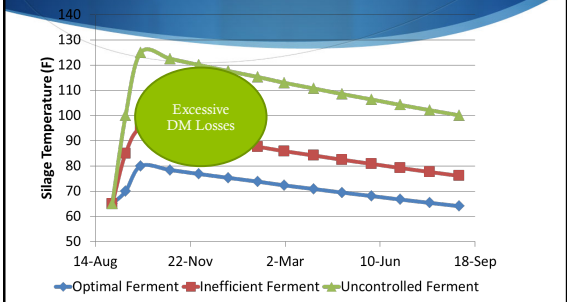
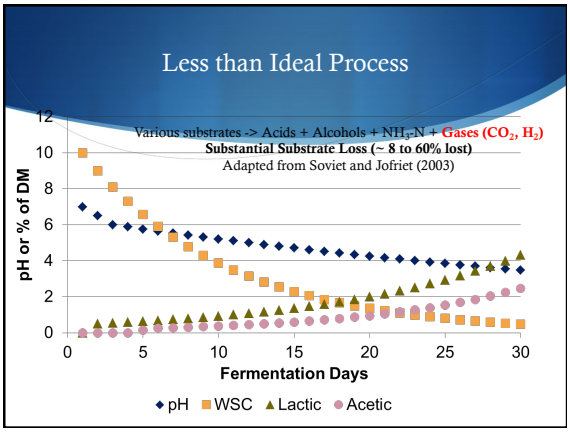


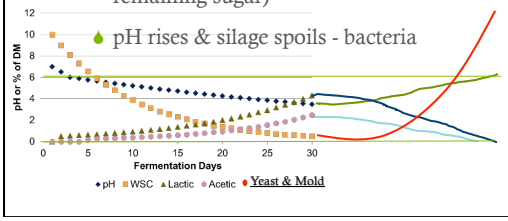
Image courtesy of Dr. Monty Belmer, DVM
Waupun Veterinary Service

Less than Ideal Process



Feed-out challenge: Aerobic Instability

- Silage re-exposed to air and unstable
- Wild yeast grow, consume acids (and remaining sugar)
- pH rises & silage spoils - bacteria



Feed-out Opportunities

- Limit aerobic exposure
  - At the feed-out face
  - Maintain density
- Consider tools to improve forage stability or yield ***clean feed***
  - Treatment/preservative

Goeser et al. (2015) Meta-Analysis

	Legume	Grass	Corn Silage	Small Grain
Fermentation Shrink (% of original DM)				
Mean	4.3	4.4	3.2	4.0
Median	3.0	3.0	2.4	3.0
Goal**	<2.0	<2.0	<1.5	<2.0
Max	35.0 and greater			

Fermentation Analysis Goals

Corn Silage	Published Means*	Typical***	Guideline	% RRL Met Goal?
pH	3.72	3.7 to 4.2	< 4.0	
Lactic	5.41	4 to 7	> 3.5	82.5%
Acetic	2.29	1 to 3	< 2.0	47.5%
Propionic	0.12	< 0.1	< 0.25	
EtOH	1.40	1 to 3	< 1.0	

Legumes\Grasses	Published Means**	Typical***	Guideline	% RRL Met Goal?
pH	4.63	4.3 to 4.7	< 4.5	
Lactic	6.84	2 to 10	> 3.0	70.0%
Acetic	2.01	0.5 to 3	< 1.5	61.5%
Propionic	0.04	< 0.5	< 0.25	
Butyric	0.07	< 0.5	< 0.25	

*, ** Published means were weighted by treatment number within a study and summarized from references cited. The numbers of treatments summarized from cited references were as follows: Corn Silage n = 159 and Legumes n = 36.

***Typical values adapted from those published by Kung and Shaver (2001).

Guidelines developed from Research Averages, Typical values, Rock River Laboratory means and from published references cited below.

Fermentation Analysis Goals

High Moisture Corn Grain	Published Means*	Typical**	Guideline	% RRL Met Goal?
pH	4.22	4 to 4.5	< 4.5	
Lactic	1.07	0.5 to 2.0	> 1.75	40.0%
Acetic	0.51	< 0.5	< 0.5	61.0%
Propionic	0.05	< 0.1	< 0.25	
EtOH	0.84	0.2 to 2.0	< 0.25	

* Published means were weighted by treatment number within a study and summarized from references cited. The numbers of experimental treatments summarized from cited references were 32 for High Moisture Corn Grains

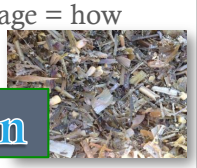
**Typical values adapted from those published by Kung and Shaver (2001).

Guidelines developed from Research Averages, Typical values, Rock River Laboratory means and from published references cited below.

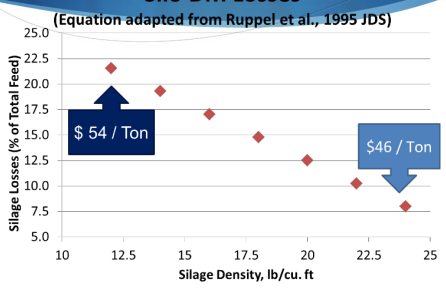
What is Fermentation Shrink?

- High quality water soluble carbohydrate (Sugar and starch)
- Must be replaced with corn or similar energy value ingredient
- 3% Shrink with 1 ton Silage = how many bushel???

½ Bushel Corn



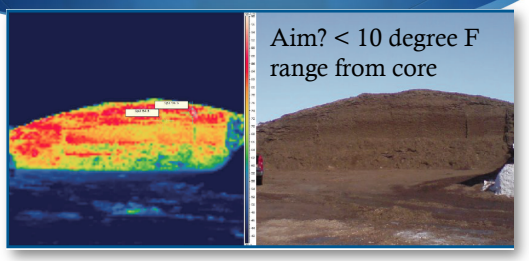
Limiting shrink losses: Packing



Keys to Limit DM Loss

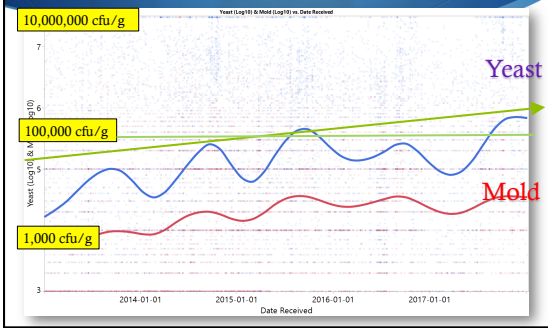
- Harvest a high quality crop & avoid rain
- Chop at the correct moisture
  - Moisture also excludes oxygen, don't go dry
- Put your decision maker on the Pack Tractor, Silo or Bagger
  - Watch the crop coming in and make key decisions
- Use a ***research proven*** inoculant at the chopper
  - Insulate the tank, mix at correct ratios and keep fresh supply
- ***Manage oxygen – keep O_2 out!***
- ***Get the pH < 5.0 ASAP!!!***

Using temperature…



(Borreani and Tobacco, 2010; Goeser et al., 2011)

Fungal load…



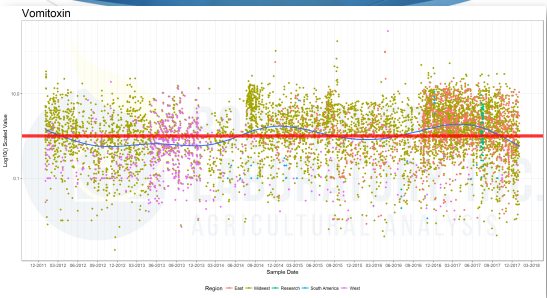
Anti-Nutrition? Mold & Yeast Guidelines

0% Spoiled

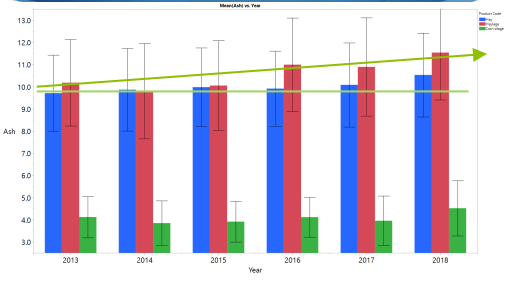
100% Spoiled

<1k CFU / gm **1m CFU / gm**

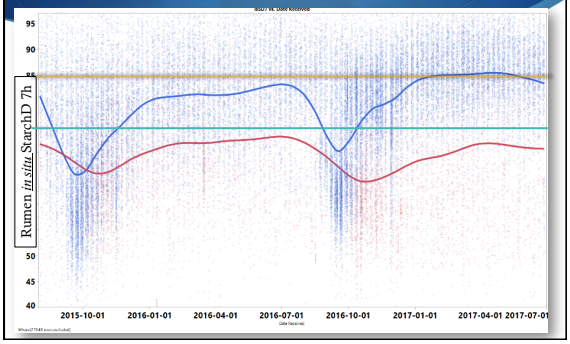
Mycotoxin insights?



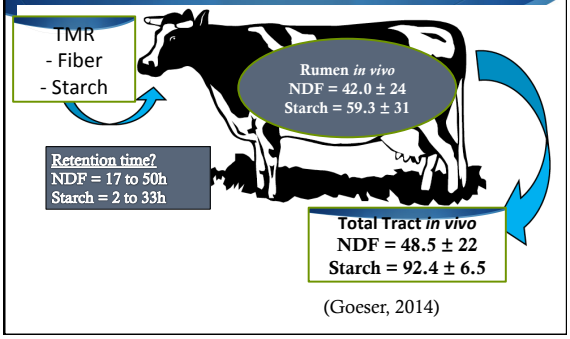
Soil (ash) content



Corn silage & Grain starch potential?

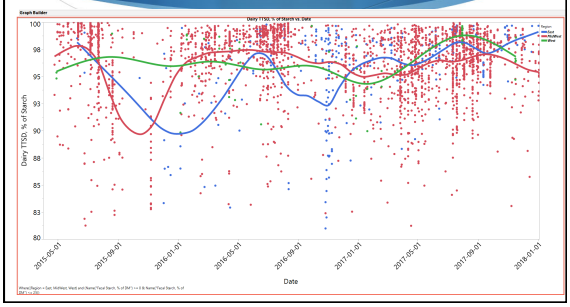


What do Cows have to say?

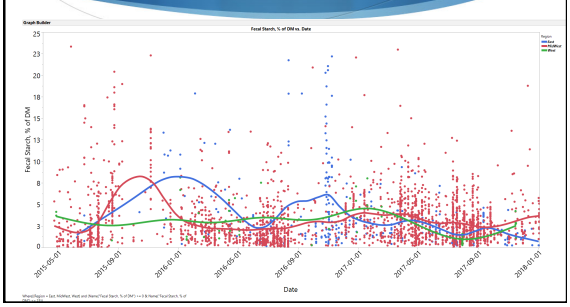


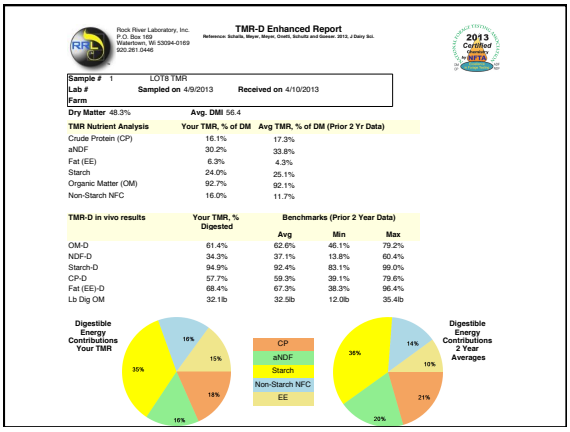
(Goeser, 2014)

Total Tract Starch Digestibility



Fecal Starch





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TMR-D Enhanced Report

2013 Certified Forage Laboratory

Sample #	1	LOT6 TMR	
Lab #		Sampled on 4/9/2013	Received on 4/10/2013
Farm			

Dry Matter 48.3% Avg. DMI 56.4

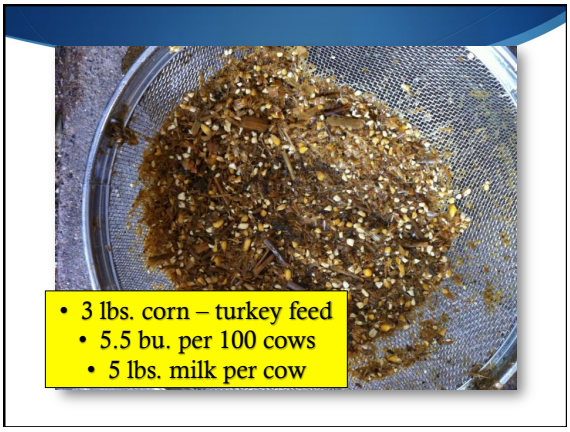
TMR Nutrient Analysis	Your TMR, % of DM	Avg TMR, % of DM (Prior 2 Yr Data)
Crude Protein (CP)	16.1%	17.3%
aNDF	30.2%	33.8%
Fat (EE)	6.3%	4.3%
Starch	24.0%	25.1%
Organic Matter (OM)	92.7%	92.1%
Non-Starch NFC	16.0%	11.7%

TMR-D in vivo results	Your TMR, % Digested	Benchmarks (Prior 2 Year Data) Avg	Min	Max
OM-D	61.4%	62.6%	46.1%	79.2%
NDF-D	34.3%	37.1%	13.8%	60.4%
Starch-D	94.9%	92.4%	83.1%	99.0%
CP-D	57.7%	59.3%	39.1%	79.6%
Fat (EE)-D	68.4%	67.3%	38.3%	96.4%
Lb Dig OM	32.1lb	32.5lb	12.0lb	35.4lb

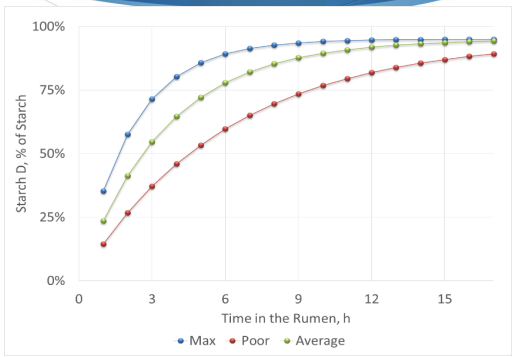
Digestible Energy Contributions Your TMR

CP
aNDF
Starch
Non-Starch NFC
EE

Digestible Energy Contributions 2 Year Averages



Starch Digestibility



StarchD developments: Commercial feed analysis

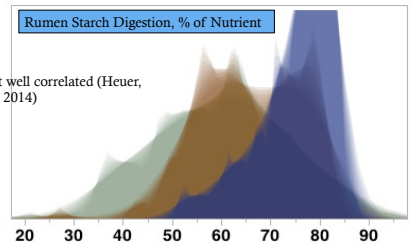
- Lab bench versus a live rumen?
  - ***In vitro*** starch digestion **not related** to commercial dairy TTSD
    - (Powell-Smith et al., 2015; Schuling et al., 2016)
  - Rumen ***in situ*** **Agrees with cows** (Schuling et al., 2016)
    - isSD7 significantly related to on-farm rumen starch digestion
    - Improved ration milk prediction (R^2 from .69 to .76)
- ***Go to the Rumen!***

Focus on the rumen…

Rumen Starch D – results summary

- **Green** = TMR reality based on *in vivo* meta-analysis
- **Brown** = predicted using k_d from 7 h *in situ* data
- **Blue** = predicted using k_d from 7 h *in vitro* data

In vitro* & *in situ not well correlated (Heuer, MS Thesis; Goeser, 2014)



Rumen *in situ* Starch Digestion Guidelines - RRL

Feed	Goal	Avg	Min
TMR	>75	60-70	<50
Corn Silage	>85	75-80	<60
HMSC	>80	60-65	<40
Dry Corn	>70	55-60	<40

In situ Rumen Starch Disappearance

Feed	h	*in situ* Rumen Starch Disappearance		
		Average	Goal	Low
Corn Silage	3	60 - 70	> 80	< 45
	7	70 - 80	> 85	< 60
	16	85 - 95	> 95	< 75
Ear Corn/Snaplage	3	60 - 70	> 75	< 45
	7	75 - 85	> 85	< 65
	16	85 - 95	> 95	< 85
High Moisture Corn	3	50 - 55	> 70	< 35
	7	65 - 70	> 80	< 55
	16	80 - 85	> 90	< 75
Dry ground corn	3	30 - 40	> 40	< 30
	7	50 - 60	> 65	< 45
	16	70 - 75	> 80	< 65
TMR	3	45 - 55	> 60	< 40
	7	60 - 70	> 80	< 50
	16	NA	NA	NA

Intestinal Digestion?!?

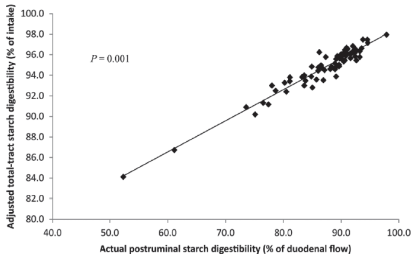
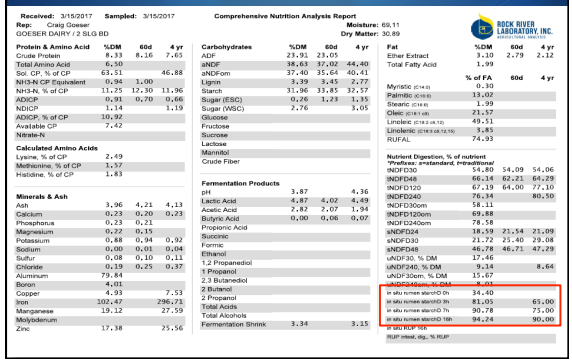


Figure 5. Relationship between postruminal starch digestibility as a percentage of duodenal flow and total-tract starch digestibility adjusted for the random effect of trial. Prediction equation: $y = 68.287 + (0.304 \times \text{postruminal percentage of flow}) + (0.013 \pm 0.574)$; n = 72, root mean square error (RMSE) = 0.58.

Adapted from Ferraretto et al., 2013

Forage Analysis Structure – StarchD



Received: 3/15/2017 Sampled: 3/15/2017
Rep: Craig Goeser
GOESER DAIRY / 2 SLG BD

Comprehensive Nutrition Analysis Report

Moisture: 69.11
Dry Matter: 30.89

ROCK RIVER LABORATORY, INC.

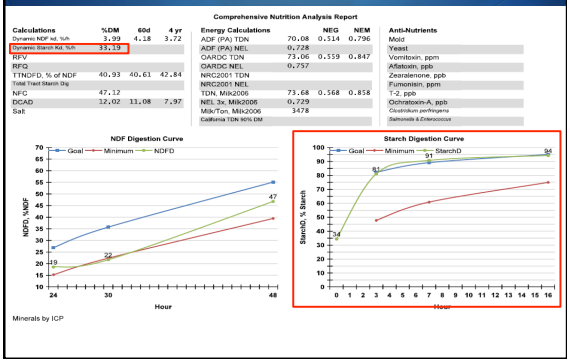
Protein & Amino Acid	%DM	60d	4 yr
Crude Protein	8.33	8.16	7.65
Total Amino Acid	6.50		
Sol. CP, % of CP	63.51		46.88
NH3-N CP Equivalent	0.94	1.00	
NH3-N, % of CP	11.25	12.30	11.96
ADICP	0.91	0.70	0.66
NDICP	1.14		1.19
ADICP, % of CP	10.92		
Available CP	7.42		
Nitrate-N			
Calculated Amino Acids			
Lysine, % of CP	2.49		
Methionine, % of CP	1.57		
Histidine, % of CP	1.83		
Minerals & Ash			
Ash	3.96	4.21	4.13
Calcium	0.23	0.20	0.23
Phosphorus	0.23	0.21	
Magnesium	0.22	0.15	
Potassium	0.88	0.94	0.92
Sodium	0.00	0.01	0.04
Sulfur	0.08	0.10	0.11
Chloride	0.19	0.25	0.37
Aluminum	79.84		
Boron	4.01		
Copper	4.93		7.53
Iron	102.47		296.73
Manganese	19.12		27.59
Molybdenum			
Zinc	17.38		25.56

Carbohydrates	%DM	60d	4 yr
ADF	23.91	23.05	
aNDF	38.63	37.02	44.40
aNDFom	37.40	35.64	40.41
Lignin	3.39	3.45	2.77
Starch	31.96	33.85	32.57
Sugar (ESC)	0.26	1.23	1.35
Sugar (WSC)	2.76		3.05
Glucose			
Fructose			
Sucrose			
Lactose			
Mannitol			
Crude Fiber			
Fermentation Products			
pH	3.87		4.36
Lactic Acid	4.87	4.02	4.49
Acetic Acid	2.82	2.07	1.94
Butyric Acid	0.00	0.08	0.07
Propionic Acid			
Succinic			
Formic			
Ethanol			
1,2 Propanediol			
1 Propanol			
2,3 Butanediol			
2 Butenol			
2 Propanol			
Total Acids			
Total Alcohols			
Fermentation Shrink	3.34		3.15

Fat	%DM	60d	4 yr
Ether Extract	3.10	2.79	2.12
Total Fatty Acid	1.99		
	% of FA	60d	4 yr
Myristic (C14:0)	0.30		
Palmitic (C16:0)	13.00		
Stearic (C18:0)	1.99		
Oleic (C18:1 c9)	21.57		
Linoleic (C18:2 c9,12)	49.51		
Linolenic (C18:3 c9,12,15)	3.85		
RUFAL	74.93		

Nutrient Digestion, % of nutrient ('Prefixes: a=standard, i=traditional'			
tNDFD30	54.80	54.09	54.06
tNDFD48	66.14	62.21	64.29
tNDFD120	67.19	64.00	77.10
tNDFD240	76.34		80.50
tNDFD30om	58.11		
tNDFD120om	69.88		
tNDFD240om	78.58		
sNDFD24	18.19	21.54	21.09
sNDFD30	21.72	25.40	29.08
sNDFD48	46.78	46.71	47.29
uNDF30, % DM	17.46		
uNDF240, % DM	9.14		8.64
uNDF30om, % DM	15.67		
uNDF240om, % DM	8.03		
in situ rumen starchD 0h	34.40		
in situ rumen starchD 3h	81.05		65.00
in situ rumen starchD 7h	90.78		75.00
in situ rumen starchD 16h	94.24		90.00
in situ RDP 16h			
RUP intest. dig., % RUP			

Forage Analysis Structure



Comprehensive Nutrition Analysis Report

Calculations	%DM	60d	4 yr
Dynamic NDF sa, %th	3.99	4.18	3.72
Dynamic Starch Kd, %th	33.19		
RFV			
RFQ			
TTNDFD, % of NDF	40.93	40.61	42.84
Total Tract Starch Dig			
NFC	47.12		
DCAD	12.02	11.08	7.97
Salt			

Energy Calculations	NEG	NEM
ADF (FA) TDN	70.08	0.514 0.796
ADF (FA) NEL	0.728	
OARDC TDN	73.06	0.559 0.847
OARDC NEL	0.757	
NRC2001 TDN		
NRC2001 NEL		
TDN, Milk2006	73.68	0.568 0.858
NEL 3x, Milk2006	0.729	
Milk/Ton, Milk2006	3478	
California TDN 60% DM		

Anti-Nutrients
Mold
Yeast
Vomitoxin, ppm
Aflatoxin, ppb
Zearalenone, ppb
Fumonisin, ppm
T-2, ppb
Ochratoxin-A, ppb
Clostridium perfringens
Salmonella & Enterococcus

NDF Digestion Curve

Starch Digestion Curve

Minerals by ICP

Corn Silage Kernel Processing Score (KPS) Guidelines and Benchmarks

Rock River Lab Data summarized by Dr. John Goeser; March 2017

% Corn Silage Starch that Passes through a 4.75mm Screen

Industry Guidelines

Industry Guidelines		Rock River Lab % of Samples in Each Range
Optimum	>70	22.5%
Average	50 to 70	55.0%
Below Average	<50	12.5%

Rock River Lab Results

Rock River Laboratory Database	
All Years	
Average	64.4
Min	51.9
Goal	>76.0

2016 Crop Year	
Average	66.0
Min	55.5
Goal	>76.4

2015 Crop Year	
Average	65.8
Min	52.4
Goal	>77.5

The Alphabet Soup

aNDFom

aNDFom

Cleans up the "contaminates" that skew the NDF analysis results

aNDFom—Nitrogen and starch contamination

- removed by treatment with sodium sulfite and amylase

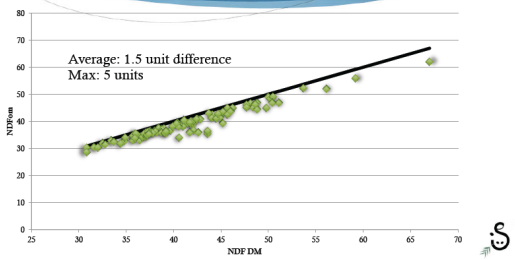
aNDFom—Ash contamination

- firing post-boiling to subtract out dirt, non-organic particles

Source of Ash Contamination

- Modern Methods of Hay making
  Discbind hay mowers act as a vacuum
- Flood Irrigation
- Soil and dirt does not solubilize in NDF solution and if not corrected for will inflate values

Alfalfa hay/haylage aNDFom



Bottomline

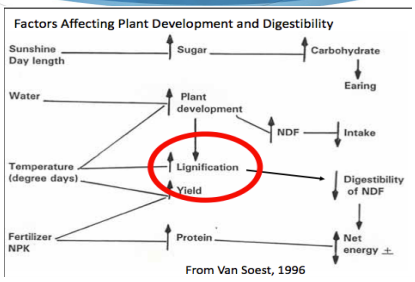
NDF content of diets, in some cases, will DROP 2-5 units

On specific forages:

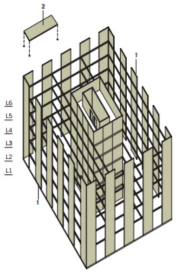
May see as high as a 8-10 point drop in NDF!

Keep in mind that this will affect the NDFD value as well!

Fiber Digestibility

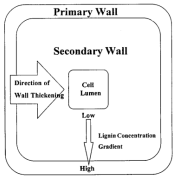


Fiber Digestibility – Maturity Impact



https://diagram+of+tall+building+structures

- **Lignin highest in primary wall & moves into secondary wall as plant matures**
  - **ML and 1° wall often indigestible (for fiber particles)**



Lignin is not Lignin is not Lignin Feedtype/Hybrids Impact

2.4 factor to calculate CHO C is NOT constant

- BMR corn silage hybrids, **3 to 5**
- Conventional hybrids **2 to 7**
- Alfalfa **1.9 to 3.2**

  (with 80% between **2.2 and 2.8**)
- Grasses **1.5 to 5.5**

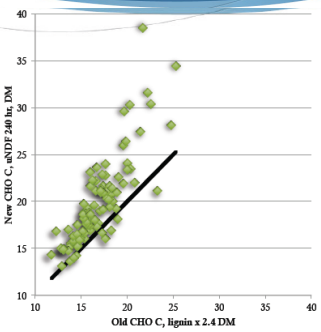
  (with immature grasses varying from **1.9 to 7.5**).

uNDF

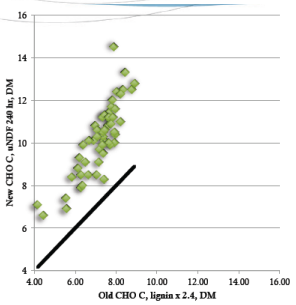
Some papers call it iNDF to represent indigestible NDF

- Mertens has pushed for us to call it uNDF for undigestible NDF and uNDF is becoming the *de facto* standard term

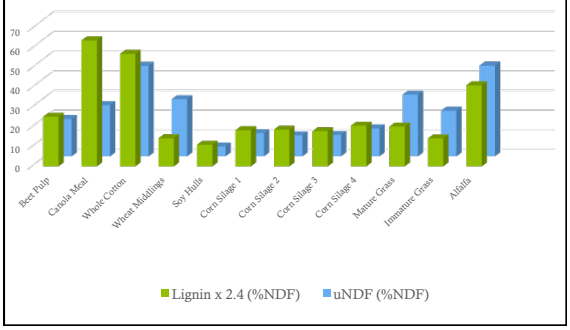
New Data Alfalfa



New Data Corn Silage



uNDF vs Lignin x 2.4 in Select Feeds

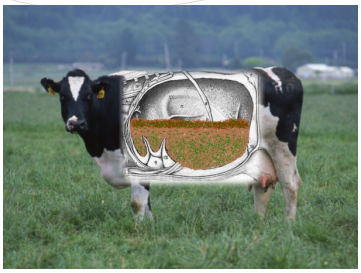


Who's got the time?

Digestibility values for forages: 30, 120, and 240

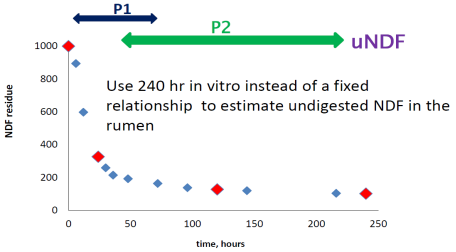
Digestibility values for non-forages: 12, 72, and 120

NDF Rates and Digestion



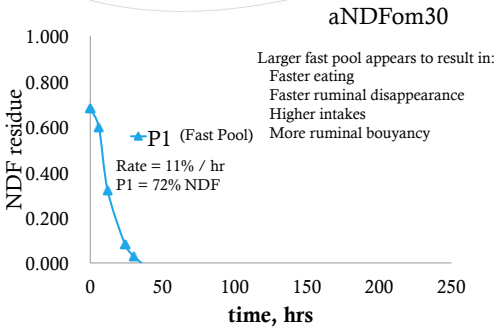
NDF kd

2 time-points + 240 hours

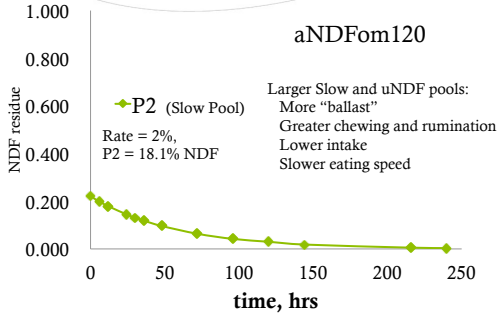


Use 240 hr in vitro instead of a fixed relationship to estimate undigested NDF in the rumen

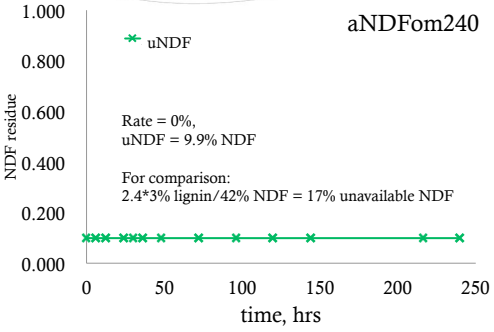
Corn silage example: fast pool



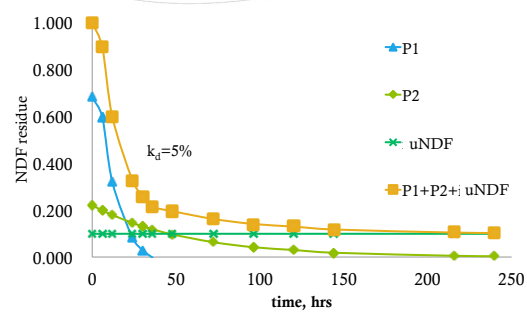
Corn silage example: slow pool



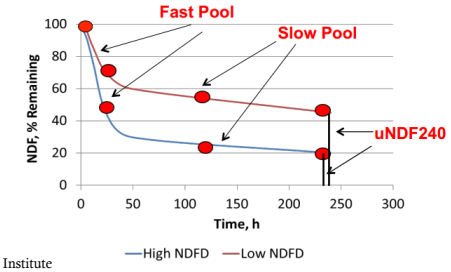
Corn silage example: uNDF



Corn silage example: P1+P2+uNDF



Using the Data



Miner Institute

Study Data—Miner Institute

Project	% of BW	Diets			
% Forage		53% 40%CS:13% HCS	67% 54%CS:13% HCS	49% 36%BMR:13% HCS	64% 51%BMR:13% HCS
2011	Intake	0.36^{ab}	0.39^{a}	0.30^{c}	0.33^{bc}
	Rumen	0.57^{a}	0.62^{a}	0.48^{b}	0.52^{ab}
	Intake: Rumen	0.625	0.632	0.633	0.637

While the $uNDFom_{240}$ intake and rumen $uNDFom_{240}$ (% BW) varied, the ratio was fairly constant

NDF Guidelines (at ~59# DMI, 99# SCM)

- Max NDFom 1.47 % BW (Range 1.26 – 1.47)
- Max Rumen NDFom 19# or 1.28 % BW
- Range of intake $uNDFom_{240}$ 0.30 to 0.48 % BW
- Range of $uNDFom_{240}$ mass in rumen is 0.48 to 0.62 % BW
- Range of $uNDFom_{240}$/ intake $uNDFom_{240}$ is 1.60 regardless of diet
- This equates to a $uNDFom_{240}$ rate of passage of about 2.64 %/ hr.

Miner Institute

Take Home…

uNDF and intake appear to be very highly correlated

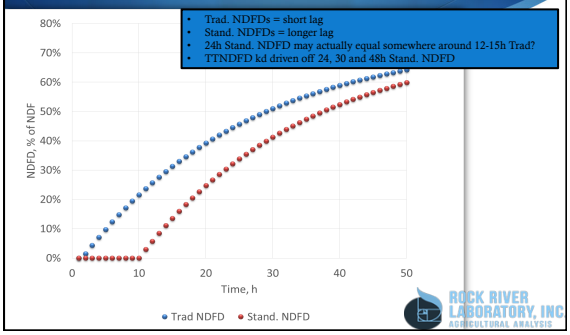
- ❖ It appears in Holsteins that the cow will reach a steady-state uNDF rumen level **4-5 kg or 8.8 to 11 lbs.**

For her to consume more feed, an equal amount of uNDF must escape the rumen first.

- ❖ uNDF has 0 kd so completely regulated by passage rate and reduction of particle size.

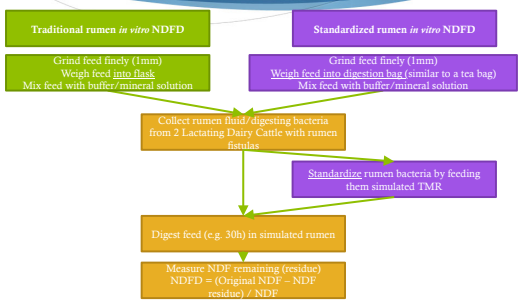
This has massive potential impact on formulation, procurement of feeds and management for crop quality.

Traditional vs RRL Standardized NDFD Methods

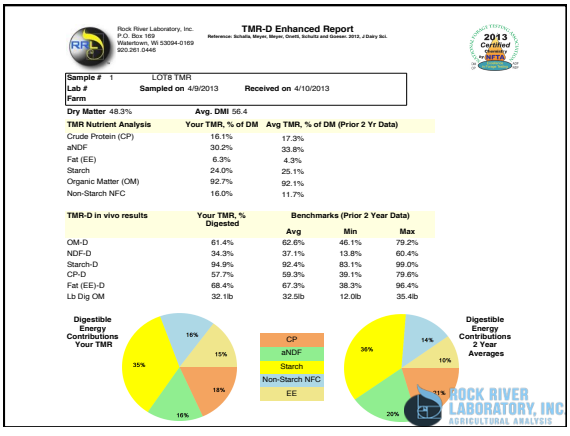


ROCK RIVER LABORATORY, INC AGRICULTURAL ANALYSIS

Traditional vs RRL Standardized NDFD



ROCK RIVER LABORATORY, INC AGRICULTURAL ANALYSIS



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TMR-D Enhanced Report

Reference: Schaba, Meyer, Meyer, Oneill, Schultz and Goeser. 2012. J Dairy Sci.

2013 Certified Forage Testing Laboratory

Sample #	1	LOT8 TMR	
Lab #		Sampled on 4/9/2013	Received on 4/10/2013
Farm			

Dry Matter 48.3% Avg. DMI 56.4

TMR Nutrient Analysis	Your TMR, % of DM	Avg TMR, % of DM (Prior 2 Yr Data)
Crude Protein (CP)	16.1%	17.3%
aNDF	30.2%	33.8%
Fat (EE)	6.3%	4.3%
Starch	24.0%	25.1%
Organic Matter (OM)	92.7%	92.1%
Non-Starch NFC	16.0%	11.7%

TMR-D in vivo results	Your TMR, % Digested	Benchmarks (Prior 2 Year Data) Avg	Min	Max
OM-D	61.4%	62.6%	46.1%	79.2%
NDF-D	34.3%	37.1%	13.8%	60.4%
Starch-D	94.9%	92.4%	83.1%	99.0%
CP-D	57.7%	59.3%	39.1%	79.6%
Fat (EE)-D	68.4%	67.3%	38.3%	96.4%
Lb Dig OM	32.1lb	32.5lb	12.0lb	35.4lb

Digestible Energy Contributions Your TMR

CP
aNDF
Starch
Non-Starch NFC
EE

Digestible Energy Contributions 2 Year Averages

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Forage Quality: Fiber Digestibility

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