Fiber Digestibility: New Ways to Measure and Why It Is Important

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Forages

- Foundation upon which nutritionally sound and economical dairy rations are built
- High quality forage = better income over feed cost
- Forage quality impacts intake, milk production and animal health

Slide courtesy Dr. Larry Chase

So, how much forage could we/should we feed, and how do we figure that out?

Three key elements of forage quality

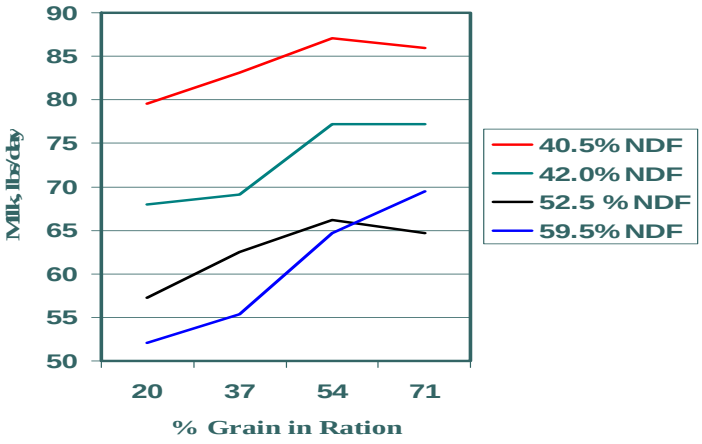
- Maturity (stage of harvest/grain fill)
  - Neutral detergent fiber (NDF) content
  - Lignin in conjunction with NDF
  - Starch content in corn silages
- Fermentation/preservation quality
- NDF digestibility
  - Related to climate/growing conditions, maturity at harvest, and genetics

Examples of high quality grass and alfalfa

Item	Alfalfa	Grass
ADF, % DM	31.2	31.4
NDF, % DM	39.6	49.6
Lignin, % DM	7.0	3.9
Lignin, % NDF	17.7	7.9

Slide courtesy Dr. Larry Chase

Alfalfa maturity - 4% FCM, lbs.



Kawas et al., (1991)

Slide courtesy Dr. Larry Chase

Alfalfa maturity - conclusions

- Feeding increased grain could not overcome the effects of lower forage quality
- Milk decreased about 1 lb./day for each day increase in maturity after prebloom
- Milk decreased by 1 lb./day for each 1% increase in alfalfa NDF content

Kawas et al., (1991)

Slide courtesy Dr. Larry Chase

Adjusting forage feeding levels based upon maturity

- Forage NDF as a % of intake
- Thumb rule – 0.9 to 1.0% of BW for lactating dairy cows
- Example
  - 1500 lb cow
    - 1500 lbs x 1.0% of BW = 15 lbs of forage NDF
  - If forages average 50% NDF
    - 15 lbs of forage NDF / 50% NDF = 30 lbs of forage DM in ration
- Helps to adjust forage feeding levels based upon harvest maturity, but does *nothing* to account for digestibility differences

NDF Digestibility

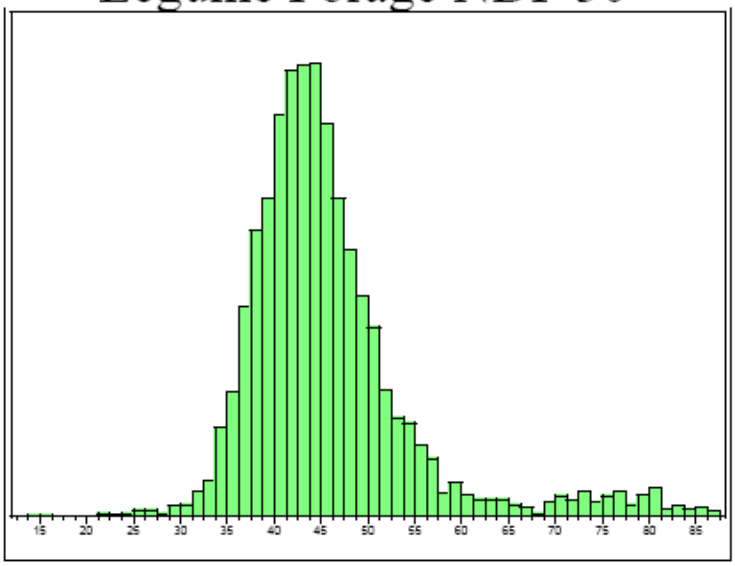
- Can be measured either *in vitro* (in the flask or porous bag) or *in situ* (in a bag hung in the rumen)
  - *In vitro* much more common
  - Timepoints usually include 12, 24, 30, or 48 hour incubations
  - Can also look at 120 and 240 h (undigested NDF)
- If have NDF and uNDF information at different timepoints, can calculate a rate of NDF fermentation (Kd) for use in ration models such as CNCPS

30 Hour NDF Digestibility

	Mean	SD
Legume Forage	45.91	9.38
MML Forage	50.91	9.36
Mixed Forage	57.82	9.89
MMG Forage	55.08	9.89
Grass Forage	51.64	11.37
Small Grain Forage	56.04	9.86
Corn Silage	58.65	6.13
Sorghum	52.67	9.92
TMR	53.58	6.43

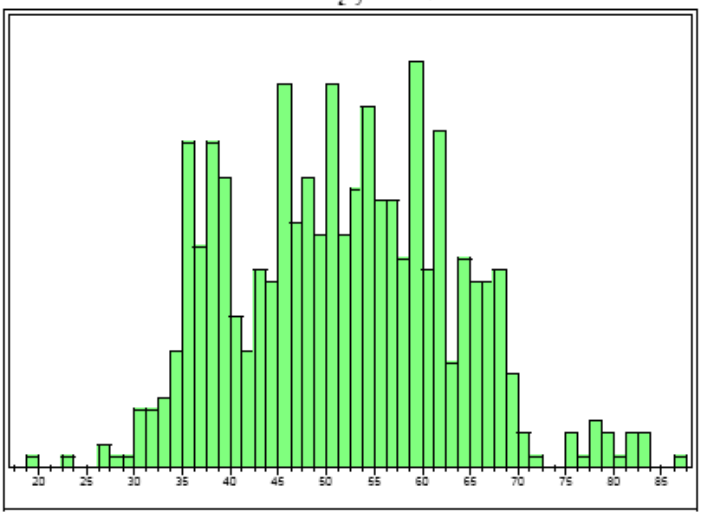
Ward, CVAS, 2008

Legume Forage NDF 30



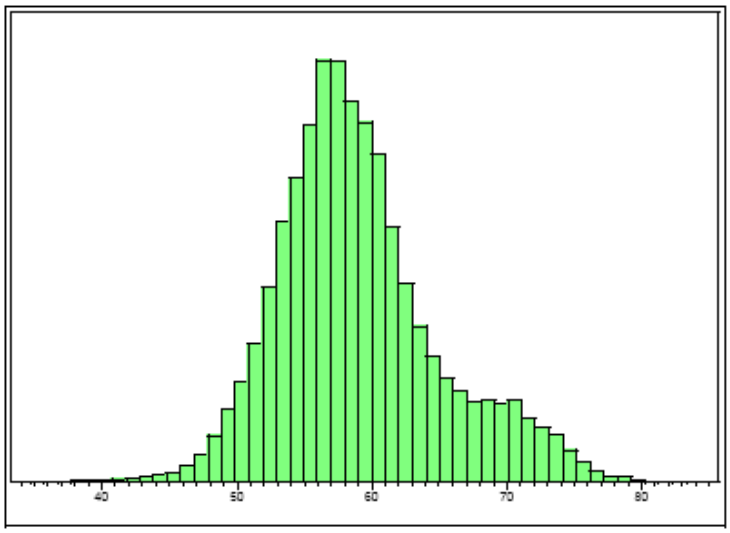
Ward, CVAS, 2008

Grass Forage NDF 30



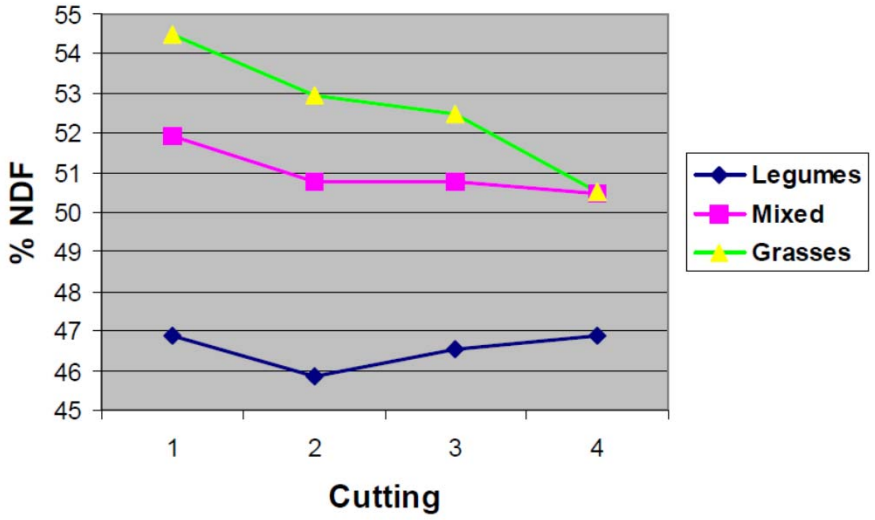
Ward, CVAS, 2008

Corn Silage NDF 30



Ward, CVAS, 2008

NDF Digestibility (30-hour) by Cutting



Ward and de Ondarza, 2007

Then and now……

Corn silage analysis, January 2013

Fibers		
Acid Detergent Fiber	22.7	% DM
Neutral Detergent Residue	38.6	% DM
Crude Fiber		
Lignin	3.52	% DM
Lignin / NDF Ratio	9.1	% NDF
Soluble fiber		
peNDF		
NDF Digestibility, Invitro		
12 hr digestibility		
24 hr digestibility		
30 hr digestibility	55.4	% NDF
48 hr digestibility		
Indigestible NDF, Invitro 120 HR		
NDF Dig. Rate (Kd)	3.84	
Non-Fibers, Structure, Utilization		
Digestible Dry Matter (fast)		
Sugar	1.3	% DM
Starch	33.1	% DM

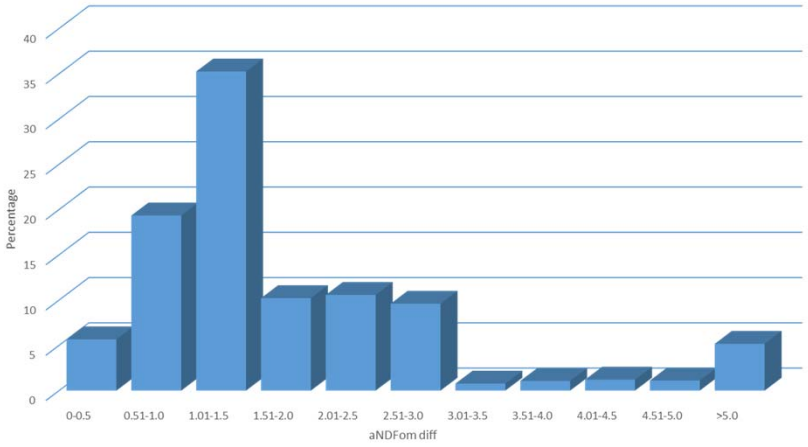
Corn silage analysis, December 2016

FIBER	%NDFom	NDFom %DM	% NDF	% DM
ADF			57.6	20.3
aNDF		35.0		35.3
NDR (NDF w/o sulfite)				
peNDF				
Crude Fiber				
Lignin			6.89	2.43
NDF Digestibility (12 hr)			33.6	11.8
NDF Digestibility (24 hr)				
NDF Digestibility (30 hr)	60.4	21.1	59.8	21.1
NDF Digestibility (48 hr)				
NDF Digestibility (120 hr)	71.8	25.1	70.9	25.0
NDF Digestibility (240 hr)	75.5	26.4	74.7	26.3
uNDF (30 hr)	39.6	13.9	40.2	14.2
uNDF (120 hr)	28.2	9.9	29.1	10.2
uNDF (240 hr)	24.5	8.6	25.3	8.9

Three big changes over past several years…

- Standardization of NDF analysis
- Correction for ash (soil contamination)
- Analysis and potential to incorporate uNDF information into forage assessment and ration formulation

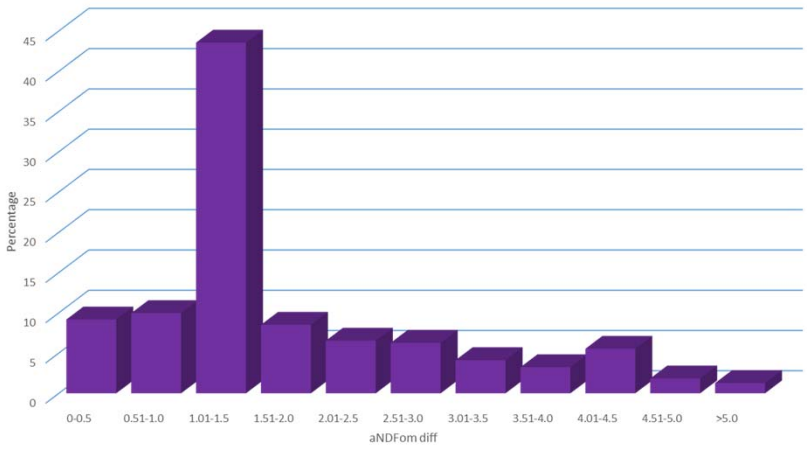
Ash correction in corn silages (aNDF – aNDFom)



Paul Sirois, 2015 Cornell Nutrition Conference

Dairy One Forage Laboratory

Ash correction in legume silages (aNDF – aNDFom)



Paul Sirois, 2015 Cornell Nutrition Conference

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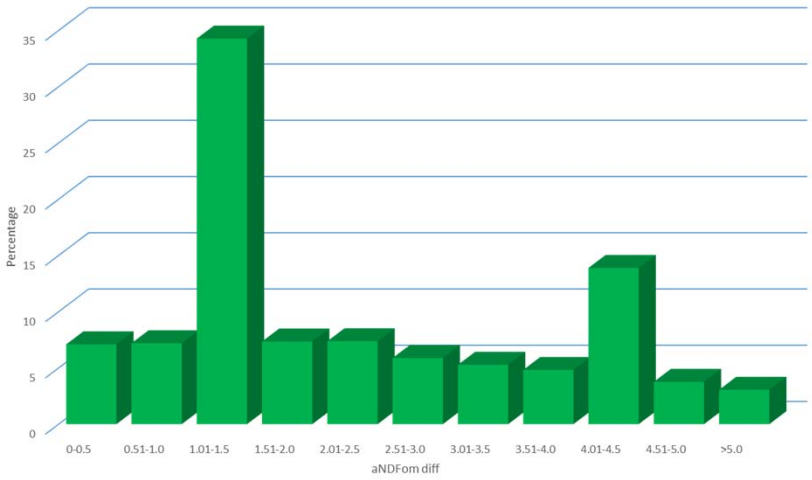
Ash correction in grass silages (aNDF – aNDFom)



Paul Sirois, 2015 Cornell Nutrition Conference

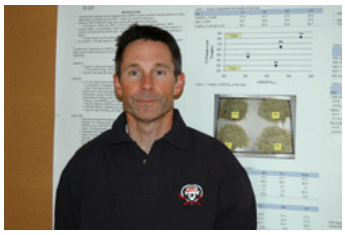
Dairy One Forage Laboratory

Incorporating fiber (in)digestibility into ration formulation

- Calculation of rate (kd) of digestion of available (potentially digestible) NDF
- Used to think indigestible NDF = lignin x 2.4 (Van Soest)
- Lignification only part of the story – also have crosslinking among components of NDF that affects (in)digestibility

Some big acknowledgements….

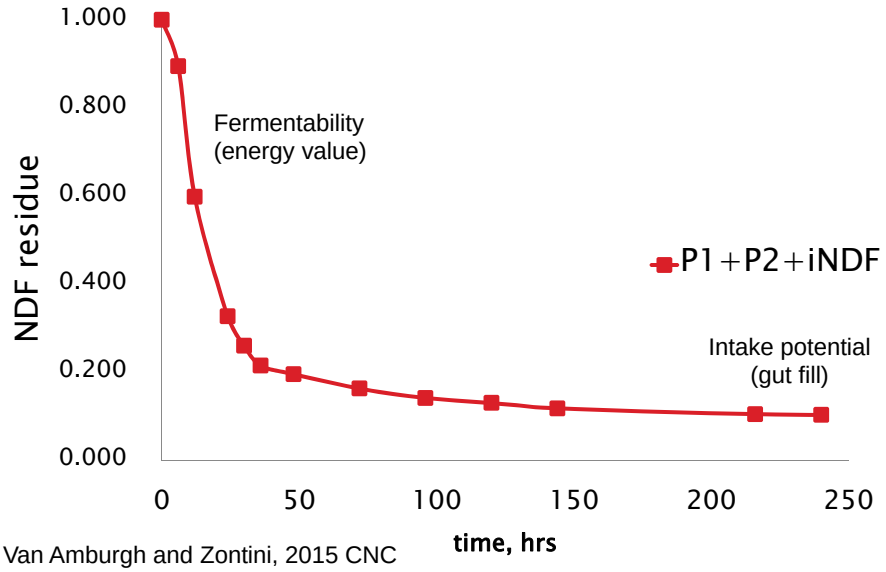
Dr. Mike Van Amburgh
Cornell University



Kurt Cotanch
Miner Institute

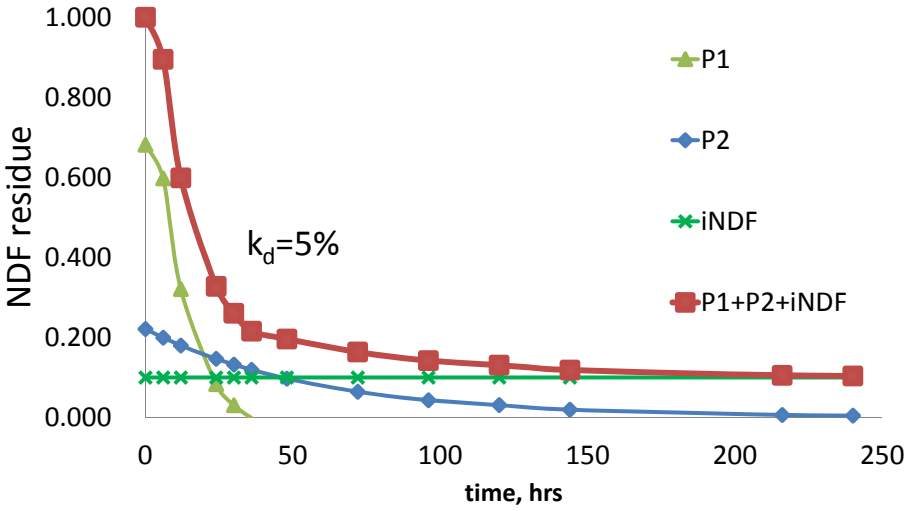
Dr. Rick Grant
Miner Institute

Corn silage example: NDF_t

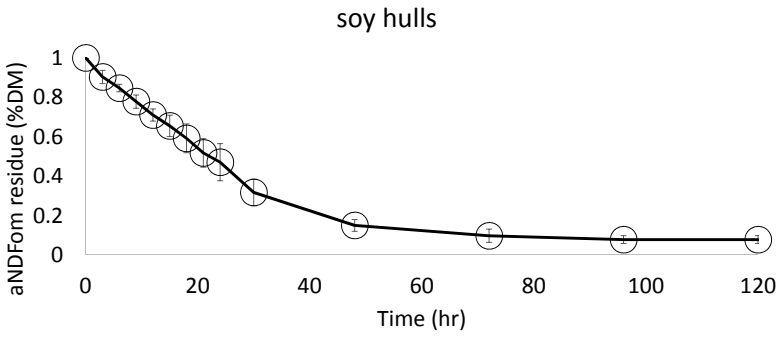


Van Amburgh and Zontini, 2015 CNC

Corn silage example: P1+P2+iNDF



aNDFom digestion of soy hulls



Zontini and Van Amburgh

Examples of high and low uNDF forages

Forages	aNDFom, %DM	uNDFom, %aNDFom	Fast, %aNDFom	Slow, %aNDFom
Alfalfa hay	38.8	51.3	35.7	13
Alfalfa silage lo-uNDFom	38.1	36.2	55.2	8.7
Alfalfa silage hi-uNDFom	40.9	42.8	33.4	23.9
BMR Corn Silage	43.8	23.7	67.8	8.5
Conv. Corn Silage	41.3	30.3	8.8	60.9

Zontini and Van Amburgh

uNDF240 values for various byproducts

Plant by-products	aNDFom %DM	uNDFom %aNDFom	Fast %aNDFom	Slow %aNDFom
Citrus pulp dry	23.1	12	92	na
Corn gluten feed	29.8	12	88	na
Corn grain	11.1	2	98	na
Delinted Whole cottonseed	50.3	43	57	na
Soy bean hulls	65.9	3	97	na
Soy Plus	18.9	2	98	na
Sunflower seed hulls	75.4	74	26	na
Wheat midds	37.4	22	78	na

Zontini and Van Amburgh

Miner Institute Project, 2011
$uNDFom_{240}$ Intake, Rumen content and Fecal

	High CCS	Low CCS	High BMR	Low BMR	Median
uNDFom, %DM	9.92%	8.24%	7.57%	6.93%	**7.90%**
uNDFom Intake lb/d	5.80	5.27	4.87	4.48	**5.07**
uNDFom Rumen, lb	9.17	8.42	7.63	7.06	**8.03**
uNDFom Fecal lb/d	5.80	5.27	4.87	4.48	**5.07**
uNDFom intake/ uNDFom fecal	1.00	1.00	1.00	1.00	**1.00**
uNDFom intake/ uNDFom rumen	0.63	0.63	0.64	0.63	**0.63**

Cotanch et al. 2014

Utilizing these new approaches in the 2016 New York State Corn Silage Trials

Predicting Milk Yield

Utilizing Cornell Net Carbohydrate and Protein System v. 6.5.5 (NDS platform)

Base diet formulated for an ME & MP allowable milk yield of 100 lbs/day

- 2nd lactation, 110 DIM, 1585 BW, 3.80% milk fat, 3.20% milk true protein
- CNCPS Feed Library Values Used for base ration
  - NDF digestibility values from 2 year average in Cumberland Valley Analytical Services database for:
    - Corn Silage, Alfalfa Haylage, Straw

Calculations

- Predicted ME Allowable Milk Yield for each hybrid
  - using same Dry Matter Intake (DMI) as the base ration
  - Library value for starch digestibility – decision for nutrition group due to uncertainty of green samples
  - Replaced Corn Silage (on dry matter basis) in base ration with each hybrid in the trial
- Calculate expected DMI – uNDF240 equivalent of the base ration
- Calculate uNDF240 intake on a DMI equivalent

Predicted ME Allowable Milk Yield, uNDF240 equivalent (lbs/day)

- Adjusted total ration DMI so the uNDF240 was equal to that in the base ration
- Reflects how much the cow actually may be able to consume based on rumen fill.

Composition: Base Ration

Ingredients	D.M. %	A.F. lbs	DM lbs	% DM
Corn Silage Proc 35 DM 40 NDF	35.00	80.00	28.00	46.87
Alfalfa Silage 20 CP 40	35.00	22.86	8.00	13.39
Wheat Straw 5 CP 79 NDF	92.00	0.54	0.50	0.84
Corn Grain Ground Fine	88.00	9.66	8.50	14.23
Canola Meal Solvent	90.17	5.05	4.55	7.62
Corn Dist Ethanol	88.80	1.01	0.90	1.51
Soybean Hulls Ground	91.00	1.32	1.20	2.01
Citrus Pulp Dry	88.57	1.35	1.20	2.01
Wheat Midds	89.00	1.12	1.00	1.67
Expeller Soybean Meal	88.00	3.11	2.74	4.59
Blood Meal Average	90.00	1.22	1.10	1.84
Bypass Fat	99.00	0.66	0.65	1.09
MinVit	95.00	1.47	1.40	2.34
Totals		129.38	59.74	

Corn Silage: Base Ration

CUMBERLAND VALLEY ANALYTICAL SERVICES
Laboratory services for agriculture ... from the field to the feed bunk.

Feed Codes: CORN SILAGE
# of Samples: 37118
Date Range: 9/1/2014 To 9/1/2016
Region: Northeast

FIBER	AVERAGE	# OF SAMPLES	ST DEV
Acid Detergent Fiber (%DM)	24.4	31594	2.46
Neutral Detergent Fiber (%DM)	40.4	31635	3.69
Lignin (%DM)	2.95	31012	0.39
Lignin / NDF Ratio	7.28	31011	0.64
peNDF	38.8	6	3.71
NDF 12 HR Digestibility (%NDF)	30	25092	4.96
NDF 24 HR Digestibility (%NDF)	52.5	364	5.89
NDF 30 HR Digestibility (%NDF)	58.2	31508	4.34
NDF 48 HR Digestibility (%NDF)	66.6	221	5.74
NDF 120 HR Digestibility (%NDF)	64.7	32509	4.91
NDF 240 HR Digestibility (%NDF)	74.9	32511	5.48
uNDF 120 HR Digestibility (%NDF)	35.3	32509	4.91
uNDF 240 HR Digestibility (%NDF)	25.1	32511	5.48

Alfalfa Haylage: Base Ration

CUMBERLAND VALLEY ANALYTICAL SERVICES
Laboratory services for agriculture ... from the field to the feed bunk.

Feed Codes: LEGUME FORAGE
# of Samples: 11135
Date Range: 9/1/2014 To 9/1/2016
Region: Northeast

FIBER	AVERAGE	# OF SAMPLES	ST DEV
Acid Detergent Fiber (%DM)	33.2	1935	3.15
Neutral Detergent Fiber (%DM)	40.8	1947	3.86
Lignin (%DM)	6.89	1907	0.87
Lignin / NDF Ratio	16.9	1907	1.46
NDF 24 HR Digestibility (%NDF)	49	15	6.73
NDF 30 HR Digestibility (%NDF)	46.8	1616	4.53
NDF 120 HR Digestibility (%NDF)	56.2	2235	9.44
NDF 240 HR Digestibility (%NDF)	59.4	2235	9.87
uNDF 120 HR Digestibility (%NDF)	43.8	2235	9.44
uNDF 240 HR Digestibility (%NDF)	40.6	2235	9.87

Nutrient Summary: Base Ration

Nutrient	% DM
CP	16.18
Soluble Protein	5.60
aNDFom	32.29
NFC	39.66
Sugar (WSC)	3.04
Starch	28.20
Soluble Fiber	4.73
EE	4.63
TFA	3.65
Ash	7.24

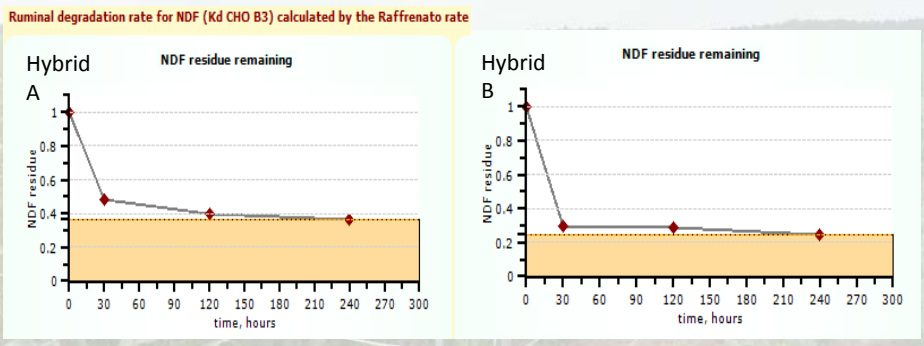
Predicted Milk Production: Base Ration

CNCPS	Supply	Balance	% Req.	Milk lbs
ME Mcal/day	69.54	0.02	100.00	100.03
MP g/day	3140.70	1.10	100.00	100.05
ME allowable ECM				103.79
MP allowable ECM				103.81

Rumen Fill: Base Ration

Parameter	Base Ration lbs/day	%DM	%BW
DMI	59.740		
uNDF Intake	5.867	9.82	0.37
uNDF Rumen	9.424		0.59
uNDF Ratio Rumen/Intake	1.610		
uNDF30 Intake	6.701	11.22	0.42

Ruminal degradation rates for selected hybrids



Madrid

Company/Brand	Hybrid	Relative Maturity	Yield, 35% DM	Dry Matter	Predicted ME Allowable Milk Yield, DMI Equivalent	uNDF240 Intake, DMI Equivalent	Adjusted TMR DMI, DMI Equivalent	Predicted ME Allowable Milk Yield, uNDF240
			tons/acre	%	lbs/day *CNCPS value*	lbs/day *CNCPS value*	lbs/day *CNCPS value*	lbs/day *CNCPS value*
84-95 days RM								
Hubner Seed	H4094RC2P	84	26.6	34.2	104.5	6.3	56.4	97.4
Kings Agri-seed, Inc.	Masters Choice MCT 4054	90	24.6	34.6	103.6	6.5	54.4	92.1
Seedway	SW3654RR	91	28.0	37.9	103.6	6.3	56.0	95.4
Dyna-Gro	D32SS56	92	28.4	34.8	104.5	6.3	56.0	96.5
Seedway	SW3600 GENSS	92	26.7	32.4	102.8	6.6	53.3	88.9
Hubner Seed	H6157RCSS	94	28.5	32.4	102.3	6.7	54.0	90.3
Kings Agri-seed, Inc.	Masters Choice MCT 4572	95	31.0	37.2	103.5	6.5	54.2	91.5
Seedway	SW3768 GENSS	95	27.2	33.7	103.2	6.5	54.3	94.4
		RM Mean	**27.6**	**34.6**	**103.5**	**6.4**	**54.8**	**93.3**
96-100 days RM								
Kings Agri-seed, Inc.	Masters Choice MCT 4632	96	26.9	34.9	105.8	6.0	59.0	104.1
Mycogen	TMF2Q419	96	28.1	34.4	104.7	6.1	58.0	100.9
Hubner Seed	H6187RCSS	97	28.3	35.0	103.4	6.6	53.0	88.9
Dairyland Seed	HiDF3197RA	97	27.3	33.5	103.7	6.4	54.9	93.3
Channel	197-68STXRIB	97	26.7	33.0	104.7	6.4	54.8	94.0
Channel	198-98STXRIB	98	31.3	34.7	105.5	5.9	59.2	104.4
Hubner Seed	H6191RCSS	99	27.9	34.1	103.5	6.4	55.6	94.7
Doebler's Hybrids	3916GRQ	99	31.3	35.5	104.9	6.2	56.4	97.6
Mycogen	F2F499	99	26.3	32.2	108.3	5.1	68.7	128.0
Dyna-Gro	D39RR12	100	26.9	33.2	105.2	5.9	59.5	104.6
Dairyland Seed	HiDF3700RA	100	29.9	32.9	103.6	6.6	53.6	90.3
		RM Mean	**28.3**	**33.9**	**104.8**	**6.1**	**57.5**	**100.1**
101-107 day RM								
Hubner Seed	H5222RC3P	101	30.4	33.3	106.0	5.6	62.3	111.6
Doebler's Hybrids	RPM 4115AM	101	29.8	34.0	106.1	5.9	59.5	105.6
Kings Agri-seed, Inc.	Masters Choice MCT 5250	102	29.0	31.9	103.1	6.6	53.1	88.6
Channel	203-44STXRIB	103	25.1	30.8	103.0	6.5	54.3	91.4
Kings Agri-seed, Inc.	Masters Choice MCT 5371	103	28.5	31.9	104.3	6.3	56.0	96.3
Doebler's Hybrids	RPM 563HXR	105	30.6	31.2	105.9	5.8	60.9	108.5
Seedway	SW5554GT	106	30.8	32.4	104.0	6.2	56.9	97.9
Kings Agri-seed, Inc.	Masters Choice MCT 5661	106	30.1	31.7	103.9	6.5	54.2	91.9
Hubner Seed	H5333RC3P	107	29.4	32.2	105.9	6.0	58.9	104.0
Channel	207-27STXRIB	107	28.9	30.0	103.1	6.2	57.0	97.2
		RM Mean	**29.3**	**31.9**	**104.5**	**6.2**	**57.3**	**99.3**

Aurora

Hybrid	Relative Maturity	Yield, 35% DM	Dry Matter	Predicted ME Allowable Milk Yield, DMI Equivalent	uNDF240 Intake, DMI Equivalent	Adjusted TMR DMI, DMI Equivalent	Predicted ME Allowable Milk Yield, uNDF240
		tons/acre	%	lbs/day *CNCPS value*	lbs/day *CNCPS value*	lbs/day *CNCPS value*	lbs/day *CNCPS value*
H4094RC2P	84	14.3	31.6	108.4	5.2	67.7	125.7
Masters Choice MCT 4054	90	14.0	32.2	107.6	5.2	67.2	123.9
SW3654RR	91	15.8	31.0	106.8	5.0	70.9	131.1
D32SS56	92	15.0	32.3	107.5	5.6	63.8	116.4
SW3600 GENSS	92	14.3	31.4	107.0	5.4	65.9	120.2
H6157RCSS	94	14.9	30.3	106.0	5.4	65.1	117.5
Masters Choice MCT 4572	95	17.1	31.3	106.4	5.5	64.2	116.0
SW3768 GENSS	95	16.7	31.1	107.6	5.4	66.4	122.3
	RM Mean	**15.3**	**31.4**	**107.2**	**5.3**	**66.4**	**121.6**
Masters Choice MCT 4632	96	17.5	33.0	107.4	5.2	67.7	124.7
TMF2Q419	96	17.8	32.4	107.7	5.2	68.2	126.0
H6187RCSS	97	17.5	33.6	107.4	5.4	65.6	120.2
HiDF3197RA	97	17.7	32.3	108.2	5.3	66.8	123.6
197-68STXRIB	97	17.4	32.0	108.1	5.0	70.0	130.4
198-98STXRIB	98	18.0	32.4	107.7	5.3	66.2	121.6
H6191RCSS	99	16.9	32.0	107.0	5.6	62.8	113.6
3916GRQ	99	18.2	32.3	107.1	5.4	65.4	119.4
F2F499	99	15.2	30.8	109.0	4.8	73.5	139.3
D39RR12	100	17.2	33.3	107.8	5.2	67.0	123.7
HiDF3700RA	100	19.1	32.7	107.7	5.2	67.1	123.7
	RM Mean	**17.5**	**32.4**	**107.7**	**5.2**	**67.3**	**124.2**
H5222RC3P	101	19.9	35.3	108.0	5.5	63.9	117.1
RPM 4115AM	101	20.5	37.2	108.0	5.4	64.6	118.6
Masters Choice MCT 5250	102	21.2	34.8	108.3	5.5	63.5	116.7
203-44STXRIB	103	19.3	34.9	107.3	5.8	60.4	108.8
Masters Choice MCT 5371	103	19.4	33.5	105.6	5.9	59.8	105.8
RPM 563HXR	105	20.1	33.0	107.5	5.3	65.7	120.6
SW5554GT	106	19.9	34.2	107.7	5.4	65.6	120.4
Masters Choice MCT 5661	106	20.3	33.2	106.9	5.7	61.4	110.6
H5333RC3P	107	18.8	34.1	108.4	5.3	66.7	123.6
207-27STXRIB	107	18.7	34.7	108.4	5.4	65.2	120.5
	RM Mean	**19.8**	**34.5**	**107.6**	**5.5**	**63.7**	**116.3**

Other approaches to incorporate these analytical methods into forage evaluation

Total Tract NDF Digestibility (TTNDFD) prediction

- Developed by Dr. Dave Combs at University of Wisconsin, Madison
- Licensed to Rock River Laboratories
- Uses in vitro analysis of NDF digestibilities at 24, 30, and 48 hours and $uNDF_{240}$

Total Tract NDF Digestibility (TTNDFD) Guidelines

Eastern, Midwestern, and Western US Forages

Summarized by Dr. John Goeser, PAS & Dipl. ACAN
Revised September, 2016

Forage	Goal	Average	Low
Alfalfa	> 50%	42.8 %	< 35 %
Corn Silage	> 48 %	41.2 %	< 35 %
Grasses	> 50 %	45.1 %	< 35 %
Small Grain Silage	> 48 %	43.5 %	< 35 %

Dr. John Goeser, Rock River Laboratories, September 2016

Summary and conclusions

- High forage quality is the cornerstone of profitable dairy rations
- Key elements of forage quality
  - Maturity (NDF and lignin content)
  - NDF digestibility/undigested NDF
  - Preservation (fermentation) quality
- Tremendous advances over past ten years relative to our ability to characterize and evaluate the impact of fiber digestibility in forages

Thanks!!

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