

# Milking Ration Fiber for All It's Worth" & "Higher Forage Diets: Promoting the Health and Productivity of Your Cows

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## Mission of Miner Institute?

*"Agriculture is the fundamental occupation. No other occupation is so vitally important to the human race, nor requires such a wide range of practical and technical knowledge..."*



## Question: What are your forage questions and challenges for 2016?

## Commercial lab assays for forage quality...are you confused yet?

- Lignin, lignin/NDF or ADF
- NDF digestibility (or uNDF) in vitro, in situ
  - 12, 24, 30, 48, 72, 120, 240 hours
- Apparent total tract digestion of NDF, TMR-D
  - uNDF<sub>120</sub> or uNDF<sub>240</sub> as marker
- TTNDFD
- Corn Silage Processing Score
- Fermentrics – gas production system
  - CHO digestion rates and Microbial Biomass Production

The list continues...

## Fiber Research Group -

## Milking forage fiber



- Economic, environmental, and nutritional factors increasingly encourage farmers to feed higher forage diets.
- Whether higher forage diets or strategic use of smaller amounts of forage, we are entering a new era:
  - Greater ability to accurately formulate diets and predict cow response to ration fiber.

## When cows consume high quality forage fiber...

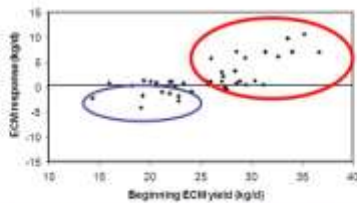


- ✓ Higher milk components
- ✓ Less metabolic disorders
- ✓ Fewer foot problems
- ✓ Greater cow longevity
- ✓ Less purchased grain
- ✓ 30% greater IOFC

[Chase, 2012]

## Response to high-NDFD corn silage by milk production level (Ivan et al., 2004)

- ✓ Overall, DMI increased by 1.4 lb/d and milk by 2.0 lb/d

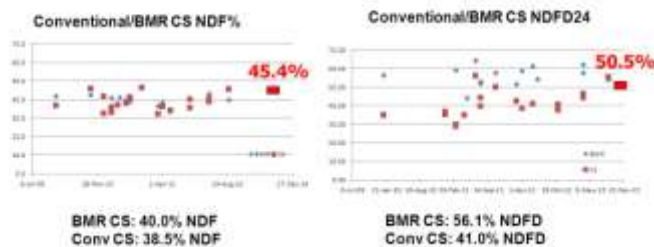


Allocation of forage by production level gets more milk from fiber!

## To make milk, we must understand fiber digestibility

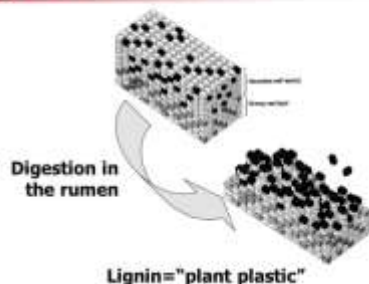
- NDF digestibility and indigestibility
- NDF physical form: particle size, fragility
- Physical and chemical attributes critical in assessing forage quality
- Related to
  - Eating, rumination, and rate of particle breakdown
  - Rumen fill and turnover
  - Dry matter intake and milk production
  - **Efficiency (rumen & milk production)**

## Corn silage NDF and NDF digestibility at Miner Institute



## Can we simply use lignin or lignin/NDF?

- Alfalfa
  - Range: 11-20%
  - Goal: <15%
- Corn silage
  - Range: 3-9%
  - Goal: <6%
- Grass silage
  - Goal: <9%



## Forage NDF digestibility and cow performance

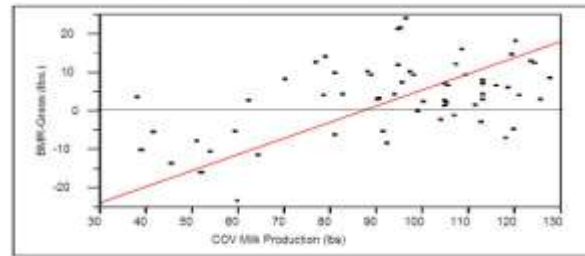
For every 1 percentage-unit increase in NDF digestibility

- +0.40 lb/d DMI
- +0.55 lb/d 4%FCM (Oba and Allen, 1999)

>40% corn silage in diet

- +0.26 lb/d DMI
- +0.31 lb/d 3.5%FCM (Jung et al., 2010)

## Milk production level and response to bmr (24-h NDFD 56%) VS grass (24-h NDFD 53%; Miner Inst., 2008)



> Mycogen F2F444 and 1<sup>st</sup> cut grass silage (ADF=32.5, NDF=51.1, CP=17.6%)

## Putting NDF digestibility measures to work...

- Relative ranking by NDF digestibility
  - Hybrid selection
  - Benchmarking
- Allocation of forages
- Troubleshooting feeding problems
- Accurate forage energy values
- Use in nutritional models for ration formulation

## Haycrop silage NDF and NDF digestibility at Miner Institute



## Measured NDFD or Estimation from Lignin?

NDF %	Lignin %	30-hr NDFD %	Rate %/h
42.3	3.01	?	?
42.6	3.32	?	?
42.6	3.24	?	?
42.6	3.24	?	?
42.3	3.18	?	?

> Corn silage data set from Van Amburgh (2005).

> Similar relationships from 36.5 to 51.8% NDF.



## Measured NDFD or Estimation from Lignin?

NDF %	Lignin %	30-hr NDFD %	Rate (kd) %/h
42.3	3.01	42.2	2.63
42.6	3.32	44.1	2.90
42.6	3.24	44.6	2.92
42.6	3.24	53.8	3.60
42.3	3.18	56.7	4.36

Need to measure fiber digestibility/indigestibility to make the most milk!

## What should we measure & monitor?

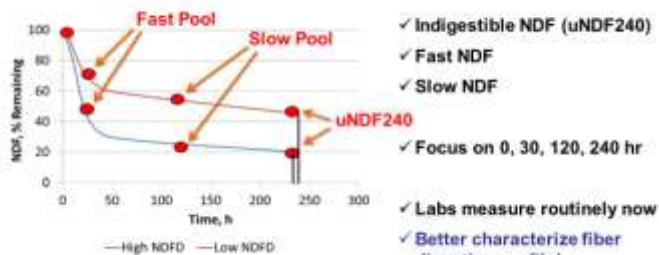
- Indigestible NDF
  - Inverse of digestible NDF
  - Highly lignified, indigestible
  - iNDF to lignin ratio is highly variable and responsive to genetics, maturity, and growing conditions
  - Useful to measure in forage testing labs
- Measured as undigested NDF (uNDF)
  - 240 hr of in vitro fermentation
  - Tilley-Terry system (artificial rumen)
  - Labs are reporting uNDF values



## Need to remember the basics of fiber quality...

- Total amount of digestible NDF
  - Potentially digestible NDF = NDF - uNDF
  - Digestible energy available in the forage
  - How far can you potentially go (gas in the tank)?
- Rate of NDF digestion
  - One vs two rates (fast- and slow-NDF)
  - "Fuel efficiency"
- Need to know both to make the most milk from the fiber.

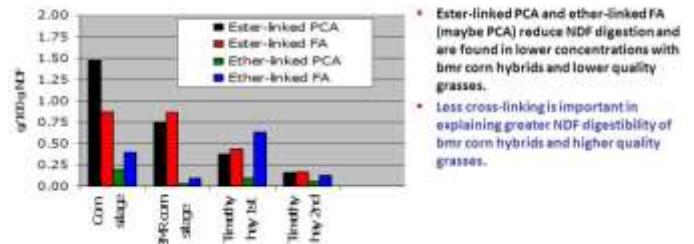
## 3-Pool Model of NDF Digestion: Better Measure of Reality?



## Rumen Fill Dynamics



## Phenolic Acids Help Explain Differences in NDF Digestibility (Dann et al., 2007)



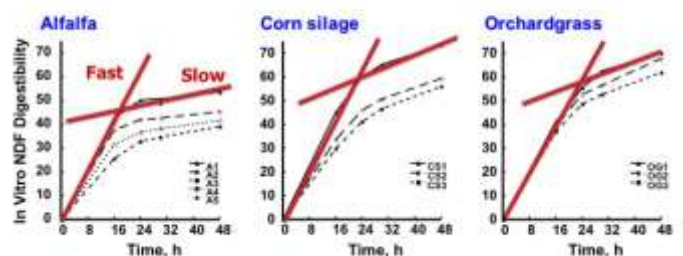
## Measured ranges in uNDF240

(source: Dairy One, May, 2015 newsletter)

- Corn silage
  - 8.7% of DM
  - Range: 2.0 to 25.5%
- Legume silage
  - 17.6% of DM
  - Range: 5.5 to 31.7%
- Grass silage
  - 15.5% of DM
  - Range: 2.3 to 44.8%

**Tremendous variation in uNDF that we need to capture when formulating diets and predicting cow response!**

## Fast and slow NDF exists in all forage types (Allen, 2005, unpublished)



Side courtesy of Dr. Mike Allen

## High NDF digestibility associated with ...

- More "fast NDF"
- Less "slow NDF"
- Less uNDF240
- Decreased eating and ruminating time per pound of NDF consumed
- Increased rumen turnover - can feed more forage
- Makes space for greater dry matter intake

## Perspectives on fast, slow, and uNDF

- uNDF -> Ballast -> Intake Constraint
- Fast/Slow NDF -> Flux -> Efficiency of Fiber Use
- Should be able to optimize efficiency
  - Ratio of Fast:Slow NDF + uNDF
- Rumen uNDF/Intake uNDF ~1.6
  - uNDF in the rumen is ~1.6x uNDF in diet
  - uNDF passes out at ~2.6%/h
  - uNDF in diet equals uNDF in feces

## Range in ration uNDF (% of BW)

- Is there a max and min uNDF240 for high-performing cows?
- Suggest:
  - 0.25 to 0.45% of BW**
  - Below range, inadequate rumen fiber
  - Above range, rumen fill constraint
  - Ratio of rumen uNDF : intake uNDF is about 1.6
  - Work in progress...

How does uNDF intake vary across stage of lactation?

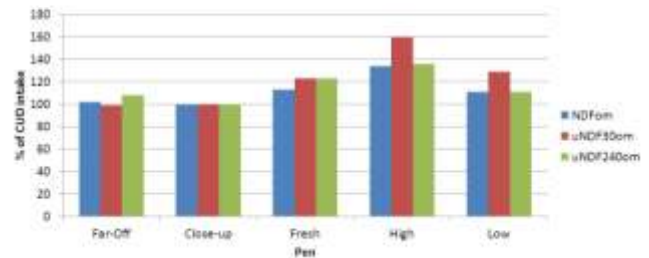
Compare uNDF30 and uNDF240 as indicators of DMI or ration transition? Can we track them as useful benchmarks?

## TMR Analyses and Ration Dry Matter Intake (Nov 2014)

Group	Ration		Tilley Terry	
	DMI kg/d	NDFom % of DM	uNDF30om % of DM	uNDF240om % of DM
Far-off	14.1	52.2	27.5	14.5
Close-up	13.6	52.7	28.8	13.9
Fresh	21.8	37.1	22.1	10.6
High	30.5	31.6	20.6	8.5
Low	24.1	33.1	21.0	8.7

✓ uNDF30 reflects Fast-NDF, Slow-NDF and uNDF240

## Miner Institute Herd TMR NDF and uNDF Intake



## uNDFom 30 vs 240 hours?

- uNDF30om better for predicting DMI?
  - How much rumen space can be "cleared" in 24 hours for next day's intake?
    - Including the amount of slow pool NDF that can also be cleared on a daily basis.
- NDFu30
  - Developed as intake prediction by FARME Institute, Larry Jones

## Milking ration fiber for all it's worth...

- Proper allocation – cow responsiveness
- Measure fiber (in)digestibility – not just lignin – amount and rate
- Developing guidelines for fast, slow, uNDF across lactation/dry period
  - Fits biology better
  - More accurate ration formulation
  - Useful benchmarking and prediction of cow responses



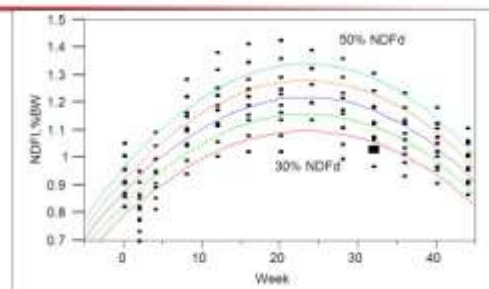
## What is a High Forage Diet?

- >50, >60, >70, or >80% forage?
- High corn silage - Do you consider CS a forage?
- Grasses versus legumes?
- Changing definition year to year?
  - Inventory/growing conditions

## How much NDF can be consumed? How long does it take?

- 1.25% of body weight is optimal**
  - Point of maximum milk production
- 1.50+% with high-bmr corn silage
- 1.80% with pasture
- We've underestimated the Intake Potential of high quality forage-NDF**

## Effect of NDFd on NDF Intake (Mertens, 1990)





## How Much Forage is Being Fed to Dairy Cows? (Chase, 2012)

	A	B	C	D	E	F	I	N	Pasture
Milk (lb), formulated	80	90	75	90	85	90	100	85	49
% Forage	58	58	59	59	67	58	82	57	100
F-NDF, % of BW	0.93	1.06	1.04	0.96	1.16	0.88	1.00	1.02	1.60

➤ How much Forage-NDF can a dairy cow consume?

## High Quality Forages: Bottom Line (Miner Farm Report, Dec. 2012)

- Total ration 24-hour NDF digestibility needs to be >60%
  - Harvest grasses at vegetative/boot stage with NDF<52%
  - Harvest legumes at bud stage with NDF<43%
  - Select corn hybrids based on higher fiber digestibility and starch content & digestibility
- For silages pack density >45 lb/ft<sup>3</sup>, DM 32-35%
- Use "Hay in a Day" technology

## How much more forage can be fed with higher NDF? (Mertens and Huhtanen, 2007)

➤ Forage mix of 25% alfalfa (40% NDF):75% grass (55% NDF)

Target milk (kg/d)	35	40	45
Grass 48-h NDFD 60%			
Forage, % of diet	61	54	48
Grass 48-h NDFD 76%			
Forage, % of diet	71	63	55

+10%      +9%      +7%

How high can NDF digestibility go?  
65-80% for grasses  
50-60% for legumes

**Forages harvested too mature, too dry, too wet, or loosely packed will not work in higher forage rations!**

## Targeted Allocation of Forages is Critical with Higher Forage Diets

- Segregation of forages is needed
- Assessments of chemical composition and digestibility (NDF and starch) of forages allows forages to be targeted to the appropriate group of cows



## Cows Varying in Milk Yield and Stage of Lactation Vary Greatly in Response to Forage Type and Digestibility

- High producing cows should be fed diets that are less filling and highly fermentable to maximize DMI
- Low producing cows should be fed diets that are more filling and less fermentable
- Both groups can be fed high forage diets – source of forage should be different

(Oba and Allen, 1999; Allen, 2011)

## Interaction of Management and Forage Fiber



## Fiber influences eating behavior...

- As ration fiber content increases:
  - Increased time spent eating
  - Longer meal length
  - More sorting
- ✓ 10-30% of energy provided by feed can be used for chewing with higher NDF, lower digestibility forages.

## Forage NDF and time spent eating

	Low CCS 53% forage 40%CS:13% HCS	High CCS 67% forage 54%CS:13% HCS	Low BMR 49% forage 38%BMR:13%HCS	High BMR 64% forage 51%BMR:13%HCS
TMR NDF, % of DM	32.1	35.6	31.5	35.1
TMR 24-h NDFD, %	56.3	54.0	62.0	60.3
Eating Behavior				
Eating, h/d	4.6 <sup>ab</sup>	5.1 <sup>a</sup>	4.1 <sup>b</sup>	4.6 <sup>b</sup>
% of TCT	34.7	35.7	35.1	33.8

<sup>ab</sup> Least squares means within a row without a common superscript differ ( $P \leq 0.05$ ).

- Higher forage diets with slower fermenting forage-NDF take longer to process.
- Time budget challenge especially when overstocked at feed bunk or mixed parity pens.

## Higher Forage Diets: Feeding Management

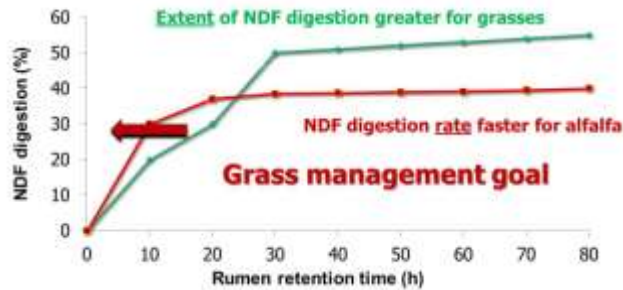
### Cow and Feed Management

- Need more time to eat
- Need more bunk space
- What is the stocking density?
- Feeding frequency?
- Feed push-ups?
- Ration "shelf-life"
- Resting time

## Grass versus legume: different rumen dynamics

- Legumes have more fragile NDF and particle size decreases more rapidly with rumination.
- Grasses increase amount of long particles, retain more small particles, contribute to slower passage rate.
  - More selective retention
  - Increases rumen fill and mass of physically effective NDF
  - Can reduce DMI if grass in not high quality

## Grass versus legume digestion in the rumen

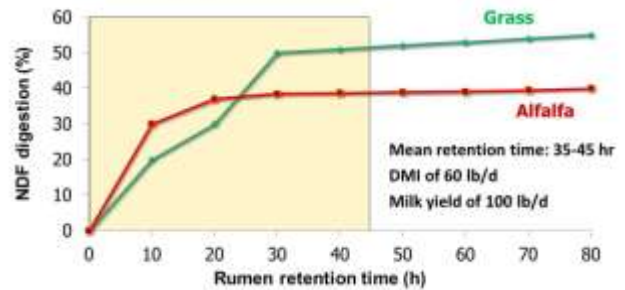


## Effect of maturity and species on digestibility (Mertens, 2007)

Forage	Maturity	Rate (%/h)	dNDF (% NDF)	Lignin (% DM)
Legume	Average	11.6	51.2	9.6
Grass	Average	9.6	68.7	6.2
L + G	Immature	15.2	72.4	4.6
L + G	Mature	6.0	47.4	11.2

Maturity effects on NDF digestion are more important than effects of plant species.

## Grass versus legume digestion in the rumen



## Targets for forage NDF digestibility ...

Nutrient	Alfalfa, Mean	Alfalfa, Normal range <sup>1</sup>	Grass, Mean	Grass, Normal range
NDF, % of DM	43.7	38.2 - 49.3	56.7	49.9 - 63.4
Lignin, % of DM	7.4	6.1 - 8.6	5.2	3.5 - 6.8
30-h NDFD, %	51.5	45.4 - 57.6	63.3	56.4 - 70.1

<sup>1</sup>Mean plus/minus one standard deviation.  
Source: DairyOne Forage Lab, Ithaca, NY.

Need to target higher NDFD to maximize response to grass forage!

## Forage quality can change rapidly in the field!

- Alfalfa, Wisconsin data (2009)
  - Crude protein, -0.25 units/day
  - NDF, +0.43
  - NDF digestibility, -0.43
- Cornell Data (2010):
  - NDFD decreases by 0.5 to 1.0 unit/d for alfalfa
  - Grass decline is even faster!

## Making the Most of Highly Digestible Forages

High quality forage **DOES NOT ASSURE** high milk production

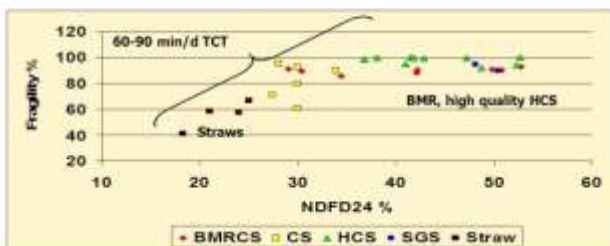
But low quality forage **GUARANTEES** low milk production!



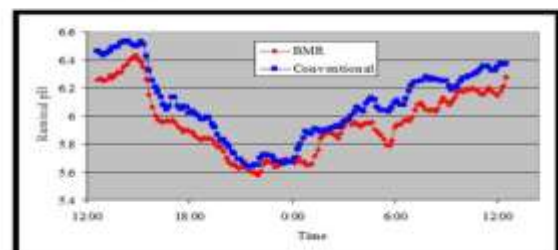
## Food for Thought:

Have we undervalued the role of rumen fiber digestion in turnover and intake?

## Greater fiber digestibility enhances forage fragility (Cotanch et al., 2008)



## Rumen pH for cows fed bmr or conventional corn silages (same particle size)



Particle size does not tell entire story!



### Importance of rumen digestion: Corn silage NDF (47-h in situ)



### Grass silage NDF (47-h in situ)



### Wheat straw NDF (47-h in situ)



### Bottom Line ...

- We are close to being able to better model effects of rumen NDF digestibility and indigestibility.
  - Version 7 of CNCPS, other models?
  - For now, monitor and benchmark forages
- Exciting time to be feeding forages to dairy cows!
- Stay tuned...



## Making Quality Hay for On-Farm, Domestic and Export Markets *Producer Panel*

Panel presentations are always a highlight at any conference, and this will be no exception. Each location will host two producer panelists. In Shakespeare, we will welcome Iann Dann and Pedro Slits. Iann is the 2015 Milk Maker Forage Competition 1st place winner of both the Dairy & Grass Hay classes, and Pedro participated in the program in 2014-15 and earned Milk Maker Forage Competition runner up in the haylage, and dairy hay classes. In Winchester, the crowd will be treated to presentations from Mark Tibben and Chris Brown. Mark is the Dundas County Forage Master and Secretary of Dundas County OSCIA, and Chris is a hay producer from Yarker,

ON. His baleage won first prize in OFC's Milk Maker Forage Competition in 2015. Chris is also OSCIA's 2015 Forage Master. These panel members will provide an excellent overview of their forage operations, and we are sure they will provide you with some great take home messages!



Photo courtesy of: [www.fruitfulmarketing.ie](http://www.fruitfulmarketing.ie)