

NDF digestibility: conceptual and analytical challenges

M. S. Allen, Michigan State University

NDF digestibility: conceptual and analytical challenges

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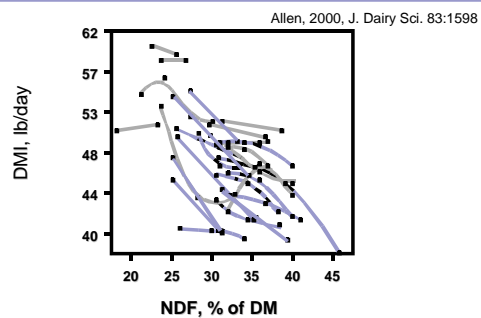
Topics

- Variation in forage fiber digestibility
- Effect on animal performance
- Maximizing benefits of enhanced fiber digestibility
- Measuring NDFD

Function of forage fiber

- Selective retention in the rumen
- Stimulation of chewing
- Increase consistency of energy supply

Feed intake decreases with increased diet forage NDF content



Why test forages for NDF digestibility?

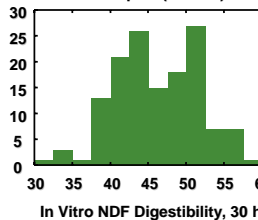
- Large variation in IVFD of forages
- Related to feed intake and milk yield
- Repeatable genetic differences among forages

Variation in in vitro NDF digestibility of forages

Allen, 1993 NRAES-67

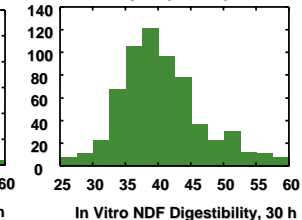
Corn Silage

Number of Samples (n = 140)



Alfalfa

Number of Samples (n = 640)



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Quantification of the effect of forage NDF digestibility on DMI and milk yield of dairy cows

Oba and Allen, 1999, J. Dairy Sci. 82:589

Comparisons (n = 13) of forages with significant ($P < 0.10$) differences in forage NDFD (in vitro or in situ) and dietary NDF content.

$$Y_{ijk} = \mu + \text{Block}_k + \text{NDFD}_j + \text{NDF}_{\text{cov}} + \text{NDF}_{\text{cov}}^2 + F \cdot C_{\text{cov}} + \epsilon_{ijk}$$

	High	Low	NDFD	NDF
NDFD in vitro, in situ	62.9	54.5		
NDFD in vivo	54.8	51.5		
DMI, kg/d	23.2	21.8	0.001	0.04
4% FCM, kg/d	28.9	26.8	0.02	0.12

1 unit of NDFD (in vitro or in situ) = + 0.17 kg/d DMI
+ 0.25 kg/d 4% FCM

What is the goal of measuring IVFD?

- Determine energy concentration
- Determine relative differences for intake potential

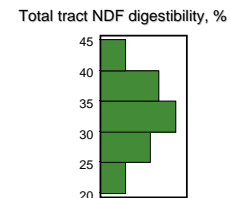
Challenges of using IVFD to adjust energy concentration

- Negative "associative" effects: ruminal pH, enzyme activity
- Variation in retention time
- Variation in intake response
- Compensatory post-ruminal digestion

Factors besides DMI affect NDFD

Oba and Allen, 1999, J. Dairy Sci. 82:135

- 28 cows fed a common diet
- Total tract NDF digestibility ranged from 21.6 to 42.2%
- DMI ranged from 21.3 to 32.1 kg/d
- <13% of variation explained by DMI as % of metabolic BW ($r^2 = 0.127$, $P = 0.06$, $\text{RMSE} = 5.5$)



Passage rate is affected by forage characteristics

Comparison of bm3 corn silage to isogenic control in 29% and 38% NDF diets (Oba and Allen, 2000, J. Dairy Sci. 83:1350)

	29% NDF		38% NDF		Significance, P		
	bm3	control	bm3	control	NDF	CS	NDFxCS
INDF kp, h^{-1}	3.73	3.13	3.55	3.27	0.81	0.0001	0.09

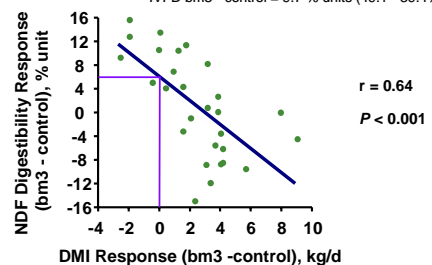
Comparison of alfalfa silage (43% NDF) to orchardgrass silage (48% NDF) (Voelker Linton and Allen, 2005, this meeting)

	alfalfa	orchardgrass	Significance, P
INDF kp, h^{-1}	2.93	2.52	0.03

Relationship between DMI response and NDF digestibility response

Oba and Allen, 1999, J. Dairy Sci. 82:135

IVFD bm3 - control = 9.7 % units (49.1 - 39.4%)

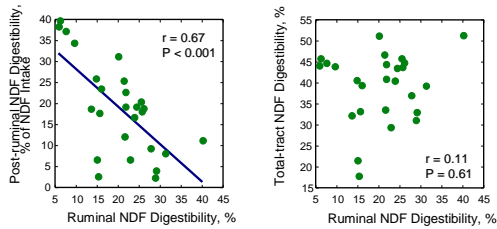


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Compensatory digestion (one example)

Oba and Allen, 2000, J. Dairy Sci. 83:1333-1358



DMI response to enhanced IVFD

Extent to which feed intake is limited by ruminal distension

- Appetite
- Forage NDF digestibility
- Forage family
- Forage NDF concentration of diet

Enhanced intake and production of cows offered ensiled alfalfa with higher NDFD

Dado and Allen, 1996, J. Dairy Sci. 79:418

- 2 alfalfa silages, similar NDF concentrations, different NDFD
- Fed to lactating dairy cows, (13 DIM) at 83% of diet DM

	Low	High	significance, <i>P</i>
DM, %	33	33	
NDF, % DM	40.4	40.1	
24-h IVNDFD, %	39.6	44.8	
NDF, % DM	40.6	38.8	
24-h IVNDFD, %	38.3	40.2	
DMI, kg/d	19.4	20.4	< 0.01
Milk Yield, kg/d	36.3	38.2	0.02

Effect of brown midrib corn silage on DMI of high producing dairy cows

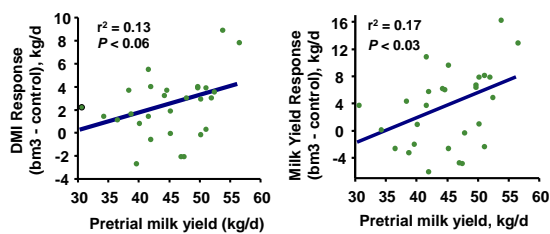
Oba and Allen, 1999, J. Dairy Sci. 82:135

- Fed to lactating dairy cows, (89 DIM) at 45% of diet DM
- In vitro NDF digestibility of bm3 corn silage was 9.7 units higher

	bm3	normal	significance, <i>P</i>
DM, %	31.7	32.6	
NDF, % DM	38.3	40.1	
Lignin, % DM	1.7	2.5	
Protein, %DM	8.7	8.4	
30-h IVNDFD, %	49.1	39.4	
DMI, kg/d	25.5	23.5	< 0.0001
Milk Yield, kg/d	41.7	38.9	< 0.0001
3.5% FCM, kg/d	41.0	38.4	< 0.0001
EB, Mcal of NE _L /d	2.8	0.7	< 0.01

Feed intake and production response to bm3 corn silage increased with milk yield

Oba and Allen, 1999, J. Dairy Sci. 82:135



Cumulative 3.5% FCM yield (kg) by stage of lactation

Longuski et al., 2000, J. Dairy Sci. 83S:294

DIM	bm ₃	control	<i>P</i>
0 - 50	1779	1753	0.75
50 - 150	3410	3198	0.02
150 - 300	3927	3796	0.50

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Symptoms of poor forage NDF digestibility

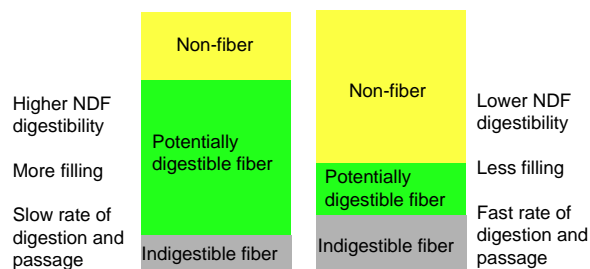
- Low cows: DMI increased
- High cows: DMI decreased
- Lower peak milk yield

Effect of forage NDF digestibility on DMI and milk yield of dairy cows

Oba and Allen, 1999, J. Dairy Sci. 82:589

- Analysis of treatment means from the literature
 - Different forage NDF digestibility (NDFD) in vivo, in vitro or in situ
 - NDFD classified as high or low
 - Blocked by experiment or treatment within experiment
- Across forage family:
 - 63 forage comparisons
 - Significant interaction of forage family (grass or legume) with NDFD
 - DMI and FCM positively related to NDFD within family
 - DMI and FCM negatively related to NDFD across family
- Within forage family:
 - 52 forage comparisons
 - DMI and FCM positively related to NDFD ($P < 0.001$)

Perennial grass Legume

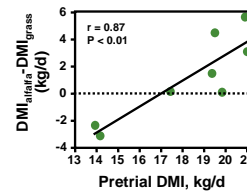


Grass vs. legume: response depends on pretrial DMI

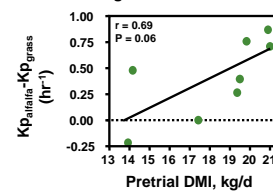
Linton and Allen, 2005, J. Dairy Sci. 88S:252

Diet had no effect on feed intake *averaged across cows*, but cows with greater drive to eat responded more positively to alfalfa over grass.

DMI response to alfalfa over grass



NDF passage rate response to alfalfa over grass



Grass in legume forages

- Grasses have much higher hemicellulose concentrations than legumes
- Grass ADF:NDF
 - Grass, immature: 0.65
 - Grass, mid-maturity: 0.60
 - Grass, mature: 0.62
- Legume ADF:NDF
 - Legume, immature: 0.82
 - Legume, mid-maturity: 0.81
 - Legume, mature: 0.82
- Target lower ADF:NDF forages to lower producing cows

Is there greater benefit of enhanced NDF digestibility for high forage diets?

Oba and Allen, 2000, J. Dairy Sci. 83:1333-1358

- **bm3 or isogenic normal corn silage**
- **Fed in high (66%) or low (42%) forage diets at 80% of forage DM**
 - **High forage diets: 38% NDF**
 - **Low forage diets: 29% NDF**

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Effect of bm3 corn silage on intake and production of dairy cows fed low or high NDF diets

Oba and Allen, 2000, J. Dairy Sci. 83:1333

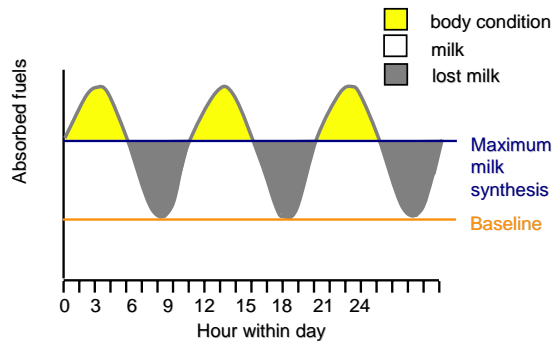
	29% NDF		38% NDF		Significance P		
	bm3	control	bm3	control	NDF	CS	NDFxCS
DMI, kg/d	24.7	23.9	22.9	21.5	<0.001	0.02	NS
3.5% ICM, kg/d	35.6	34.3	35.8	32.6	NS	0.06	NS
BW gain kg/d	1.10	0.79	0.00	-0.02	< 0.01	NS	NS
Corn grain, % of DM	26	29	0	5			

Effect of bm3 corn silage on rumen pH of dairy cows fed high or low forage diets

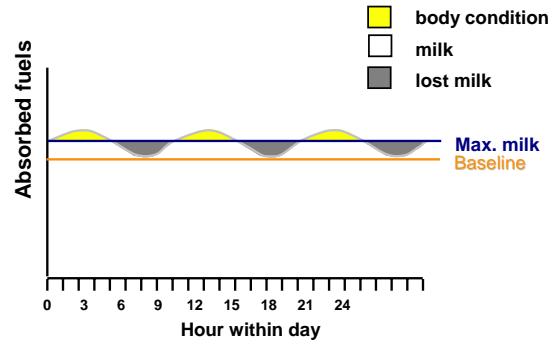
Oba and Allen, 2000, J. Dairy Sci. 83:1333

	29% NDF		38% NDF	
	bm3	control	bm3	control
Average pH	5.62	5.78	5.73	5.90
Daily pH variance	0.126	0.102	0.067	0.061

Pulsatile absorption of fuels

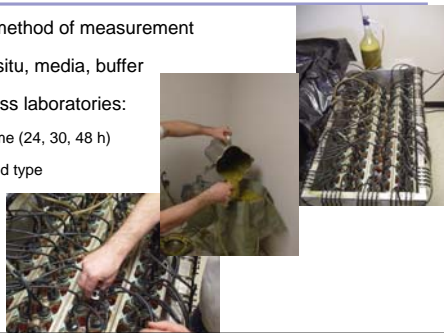


Increased baseline = more milk



Analytical challenges

- No standard method of measurement
 - In vitro, in situ, media, buffer
- Variation across laboratories:
 - Incubation time (24, 30, 48 h)
 - Grind size and type
 - Repeatability
 - Accuracy



Comparison of methods

	in vivo	in situ	in vitro A	in vitro B
Particle size	reduction	constant	constant	constant
Retention time	variable	constant	constant	constant
pH	variable	variable	constant	declining
N sources and growth factors	excess	excess	excess	limiting
Enzyme activity	variable	variable	variable	declining
Repeatability	poor	poor	high	poor

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Goal: Detect real differences in NDF digestibility

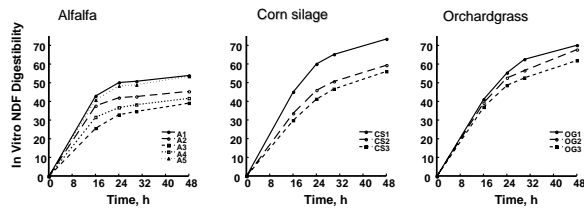
- Remove limitations to digestion of substrate
- Limitations to digestion imposed by the method (e.g. from decreased pH or limiting nutrients) will:
 - shrink differences among forages
 - increase variation within forages
 - make it difficult to compare forages

Strategies to increase repeatability of in vitro results

- Reduce variation in enzyme activity
 - Sample rumen fluid same time relative to feeding
 - Sample from 2 or more donor animals
 - Feed donor cows a high forage diet
 - Sample rumen fluid and digesta, blend under CO₂ and filter
 - Maintain temperature
- Media - provide nutrients for microbial growth
- Buffer - adequate to maintain pH
- pCO₂ - bunsen valves to provide escape of CO₂
 - HCO₃⁻ + H⁺ ↔ H₂CO₃ ↔ H₂O + CO₂

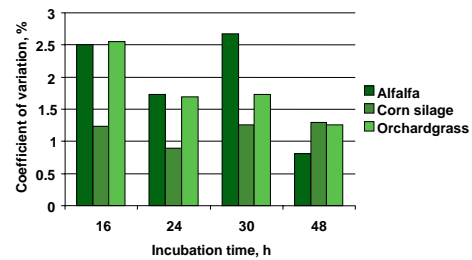
Incubation time

Mike Allen, 2005 unpublished



Incubation time: repeatability

Mike Allen, 2005 unpublished



Analyze forages, not TMRs

- Forage NDF limits feed intake more than non-forage NDF
- Forages can be allocated differently to animals
- TMRs difficult to sample

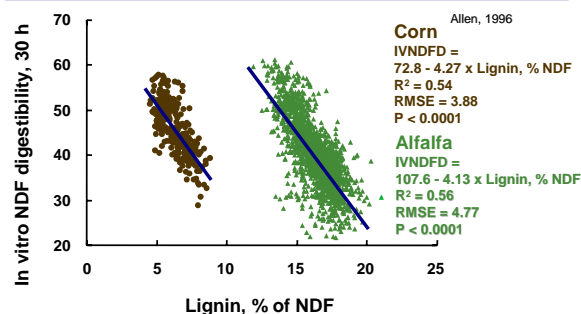
Evaluation of commercial laboratories

- Lab should run replicate samples (2 or more)
- Correlation of NDF digestibility with lignified NDF (within forage type)
- Repeatability
 - Send check samples
 - Intra-assay c.v. ~1-3%
 - Inter-assay c.v. ~4-6%

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Relationship between lignified NDF and in vitro NDF digestibility for corn and alfalfa forages



Recommendations (evaluation of laboratories)

- Method used should be substrate limiting
- Incubation time less important (be consistent)
- Duplicate samples
- Lab should provide information on accuracy and precision
 - Accuracy: correlation with lignin (% of NDF)
 - Precision
 - Intra-assay c.v. < 3.0
 - Inter-assay c.v. < 6.0

Recommendations (utilization of data)

- IVFD is a relative rank of intake potential
 - Hybrid/cultivar selection
 - Troubleshooting: switching forages (compare within run)
 - Allocation of forages (compare within run)
 - Cows with feed intake limited by distension
 - High-producing cows
 - High-fill diets
 - Maintain milk yield with higher diet NDF concentration
 - Don't compare IVFD of grasses and legumes
 - Test for ADF/NDF to determine purity of legume
- Using IVFD to adjust energy concentration is a much greater challenge

Questions?

