NDF Digestibility and uNDF: What does this mean and how can we apply it to make better decisions

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“Your nutritionist is only as good as your forage”

Dr. L. Chase

High Forage Diets: Cows Can Do It

- **Two case studies in New York**
  - **<u>Herd 1 – entire herd</u>**
    - **73-75% forage (includes corn silage)**
    - **80-85 lb/d milk (2x), 3.7% fat, 2.9% protein**
    - **NE_L=0.76 Mcal/lb**
  - **<u>Herd 2: high pen</u>**
    - **82% forage (includes corn silage)**
    - **100 lb/d milk (3x), 3.6% fat, 3.0% protein**
    - **NE_L=0.77 Mcal/lb**

(Chase, 2012)

NDF analyses

- Nutrition models/software have an input for NDF that is used primarily to calculate energy from available carbohydrates and effective fiber

- Mertens (2002) published the NDF method and gained AOAC approval – there are many approaches to measure NDF

- We would like to encourage the use of aNDFom – NDF with sulfite and ash correction – we are working to move labs in that direction

Why aNDFom?

- Hay in a hurry – wide swathing picks up dirt
- 600 hp choppers and big equipment that move fast make dust and dirt fly
- Flood irrigation moves soil
- Dirt/soil does not solubilize in NDF solution, thus if not corrected will inflate the NDF number


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27 FIELD 316 SORGHUM X SUDAN

FIBER	% NDF	% DM
ADF	56.5	34.0
aNDF		60.2
aNDFom		55.4
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin	4.95	2.98
NDF Digestibility (12 hr)		
NDF Digestibility (24 hr)		
NDF Digestibility (30 hr)	60.2	36.3
NDF Digestibility (48 hr)		
NDF Digestibility (240 hr)	74.9	45.1
uNDF (30 hr)	39.8	24.0
uNDF (240 hr)	25.1	15.1

~ 5 units

26 FIELD 308 TEST 2 SORGHUM X SUDAN

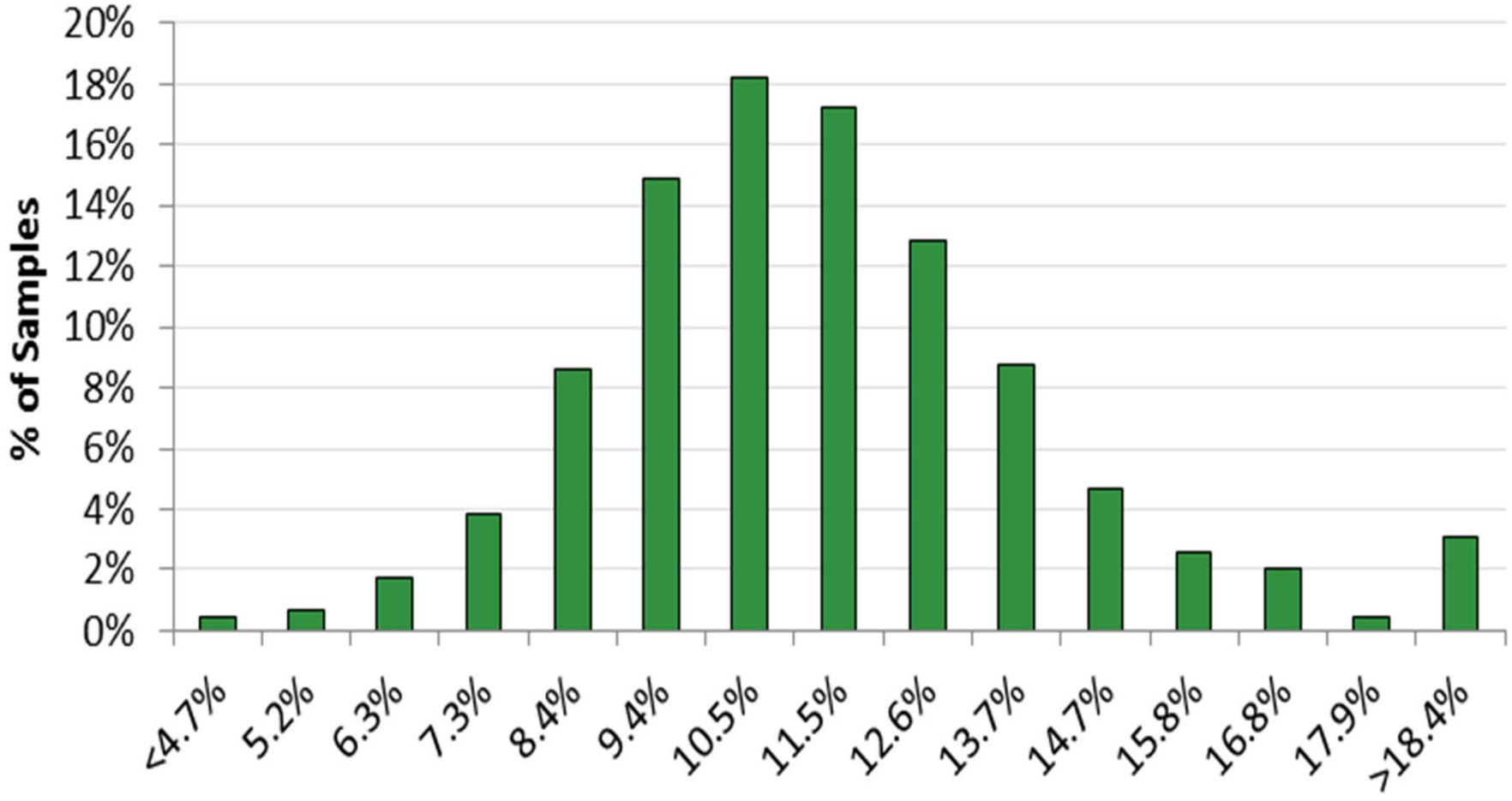
FIBER	% NDF	% DM
ADF	57.6	36.8
aNDF		63.9
aNDFom		53.7
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin	4.86	3.11
NDF Digestibility (12 hr)		
NDF Digestibility (24 hr)		
NDF Digestibility (30 hr)	49.3	31.5
NDF Digestibility (48 hr)		
NDF Digestibility (240 hr)	77.0	49.2
uNDF (30 hr)	50.7	32.4
uNDF (240 hr)	23.0	14.7

10 units

Small Grain Silage
Ash

DAIRYLAND
Laboratories, Inc.

Count 4867



Mixed Hay
Ash

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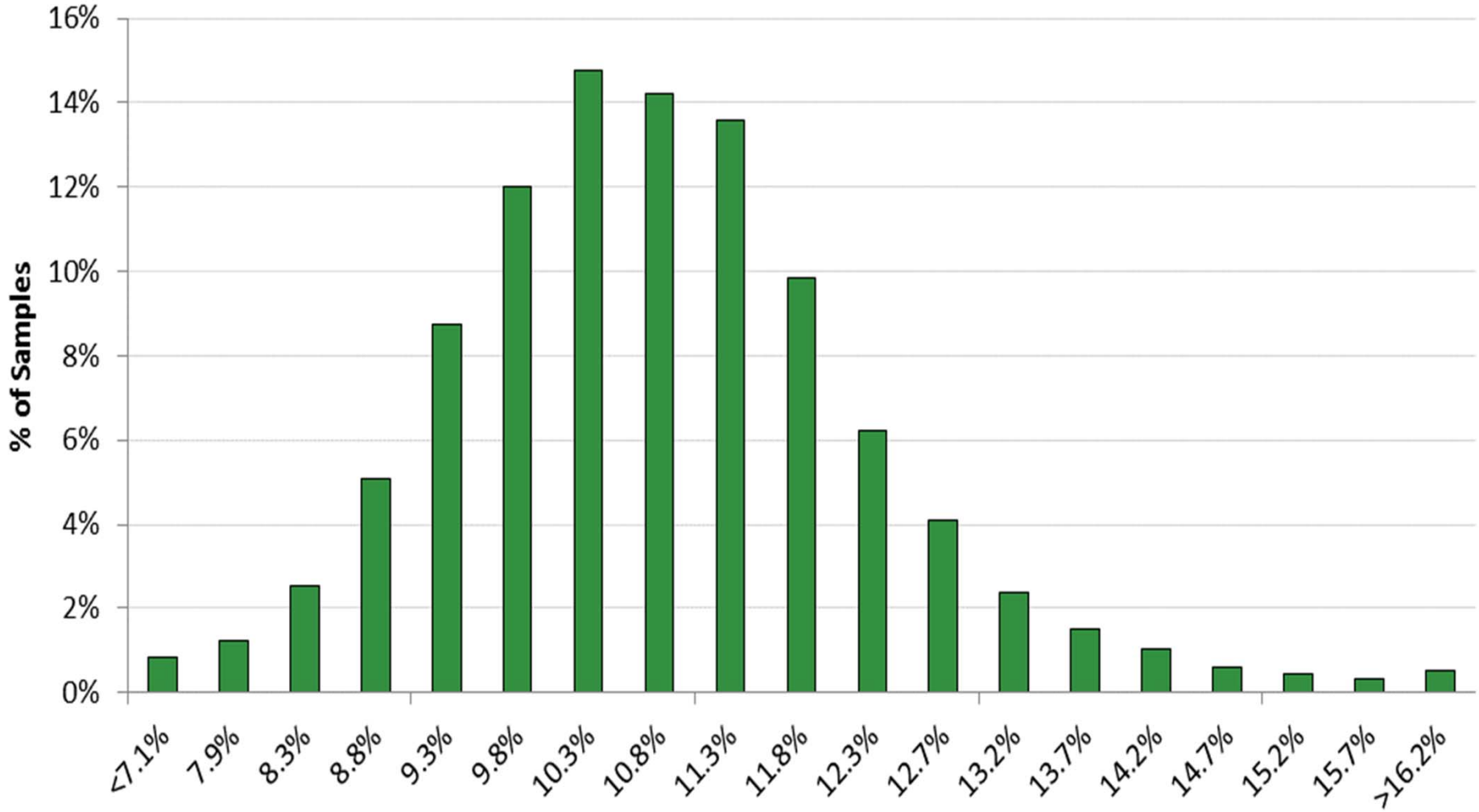
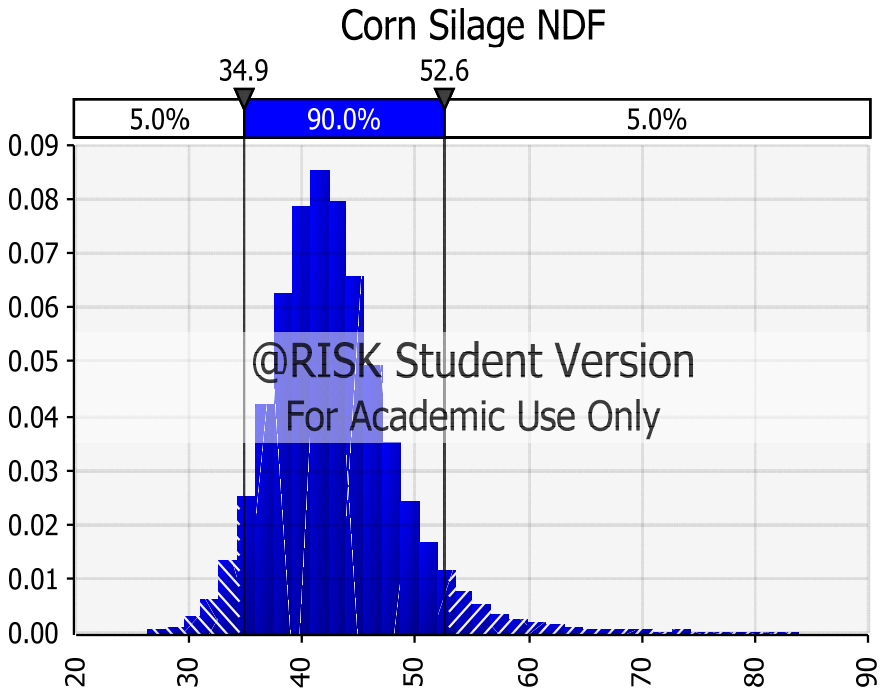
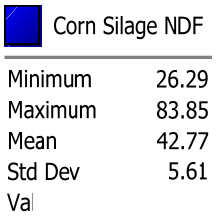
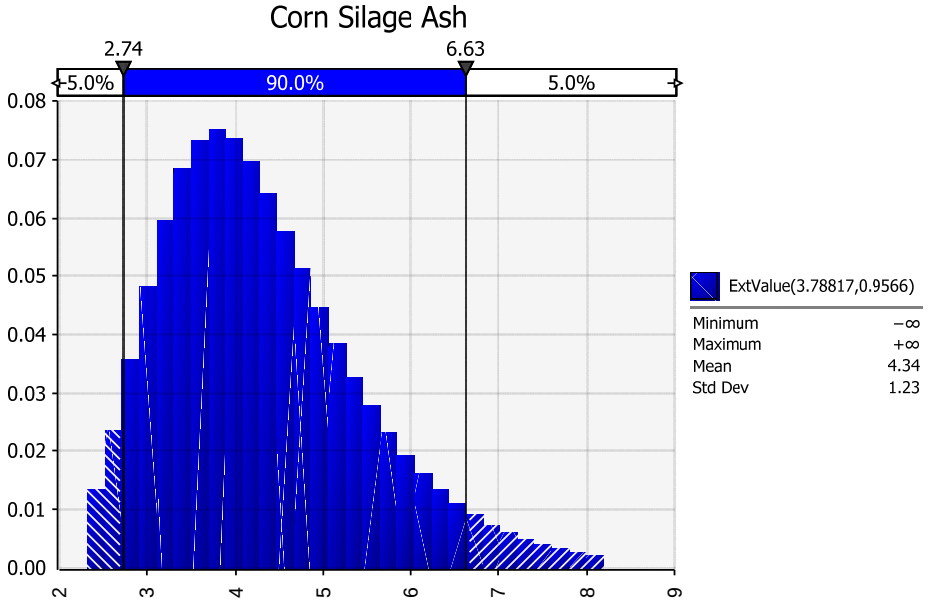
DAIRYLAND
Laboratories, Inc.



Corn silage NDF and Ash distributions from CVAS and Dairy One data bases







Higgs 2013

How do we currently characterize NDF indigestibility? (iNDF)

Models like the CNCPS use (2.4 x lignin)/NDF

Dairy NRC (2001) based on Weiss et al., 1992 use $(lignin/NDF)^{0.67}$

Van Soest and Lane Moore, 1963 USDA, Beltsville, MD right after Pete characterized NDF

Nomenclature slide - iNDF vs uNDF

Literature uses the term iNDF for indigestible NDF

We have an “Informal Fiber Working Group” that meets at least once per year around the Cornell Nutrition Conf. (Cornell, Miner Institute, Univ. of Bologna, Nutreco, ADM, Univ. of Parma, most commercial labs, Charlie Sniffen, Dave Mertens)

Mertens proposed a change in name from iNDF to uNDF –

> the NDF we call iNDF can digest, just not under anaerobic conditions, so to say indigestible is a misrepresentation – so we now use uNDF – undigested NDF

NDF Digestibility/Indigestibility

- Nousiainen et al. (2003; 2004)
  demonstrated in grasses that the relationship between lignin and digestibility was highly variable

- This was confirmed by Rinne et al. 2006 on legumes
  – methods used to determine this included 288 hr in situ (in a bag in the rumen) fermentations

- We were/are doing similar work at Cornell
  - Working to develop a procedure that could be used in a commercial lab
    Ph.D. work of Raffrenato (2011)

Corn Silage NDF Digestibility by NDF and Lignin Content

NDF, %DM	Lignin, %DM
42.3	3.01
42.6	3.32
42.6	3.24
42.6	3.24
42.3	3.18
42.3	3.00

Corn Silage NDF Digestibility by NDF and Lignin Content

NDF, %DM	Lignin, %DM	NDFD% (30hr)	Est. NDF 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	50.8	3.60
42.3	3.18	56.7	4.36
42.3	3.00	57.0	4.30

NDF Digestibility by NDF and Lignin Content

NDF, %DM	Lignin, %DM
45.0	3.52
45.0	3.26
45.0	3.32
45.1	3.18
45.0	3.43

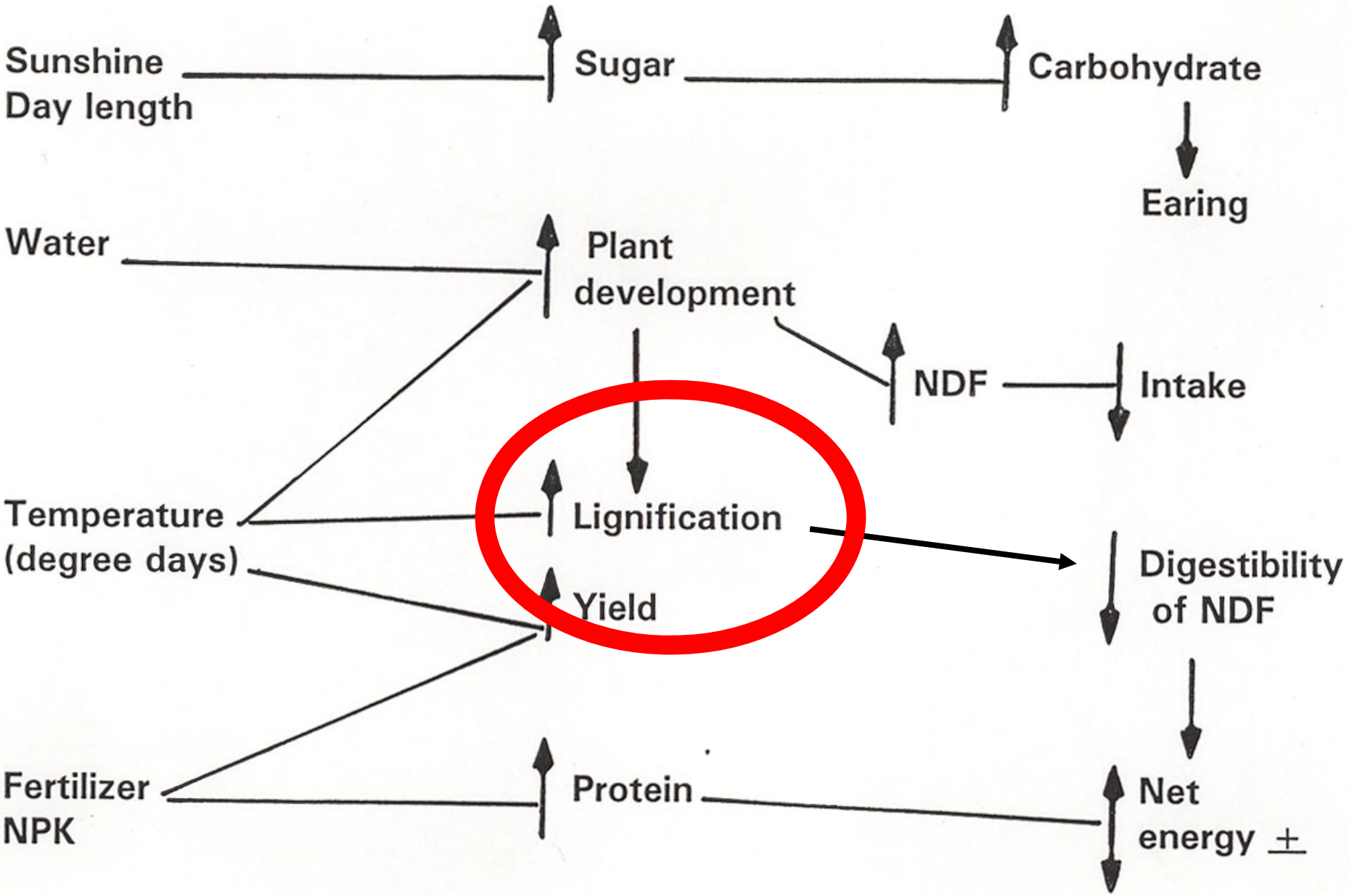
NDF Digestibility by NDF and Lignin Content

NDF, %DM	Lignin, %DM	NDFD% (30hr)	Est. NDF kd, %h
45.0	3.52	46.0	3.09
45.0	3.26	48.4	3.27
45.0	3.32	54.4	4.01
45.1	3.18	55.0	4.02
45.0	3.43	67.3	6.42

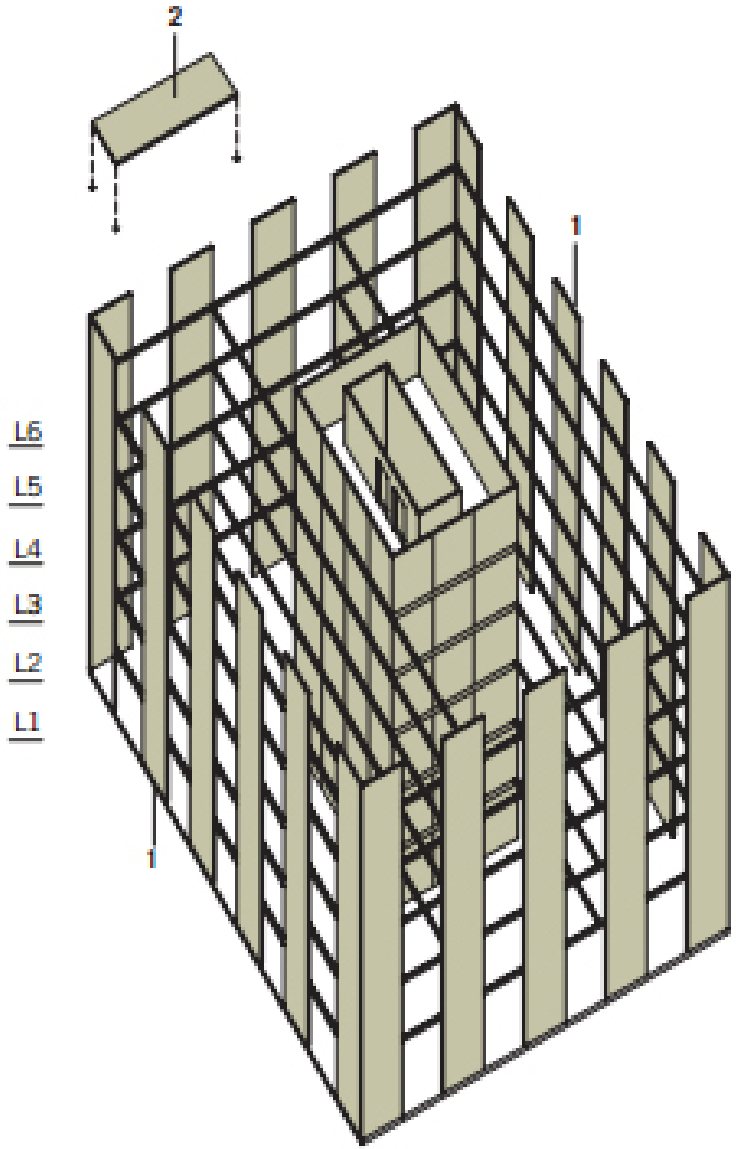
“Lignification” = cross linking between lignin and hemicellulose

- Light, heat and water interact at various stages of development
- For example, water stress causes greater cross-linking between lignin and hemicellulose
- Similar to the effect of building a very tall building

Factors Affecting Plant Development and Digestibility

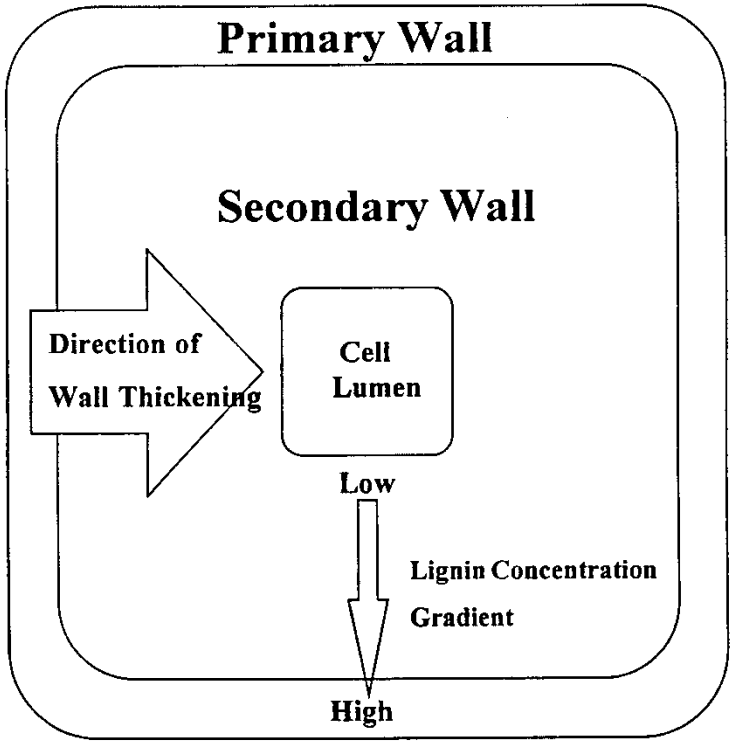


From Van Soest, 1996



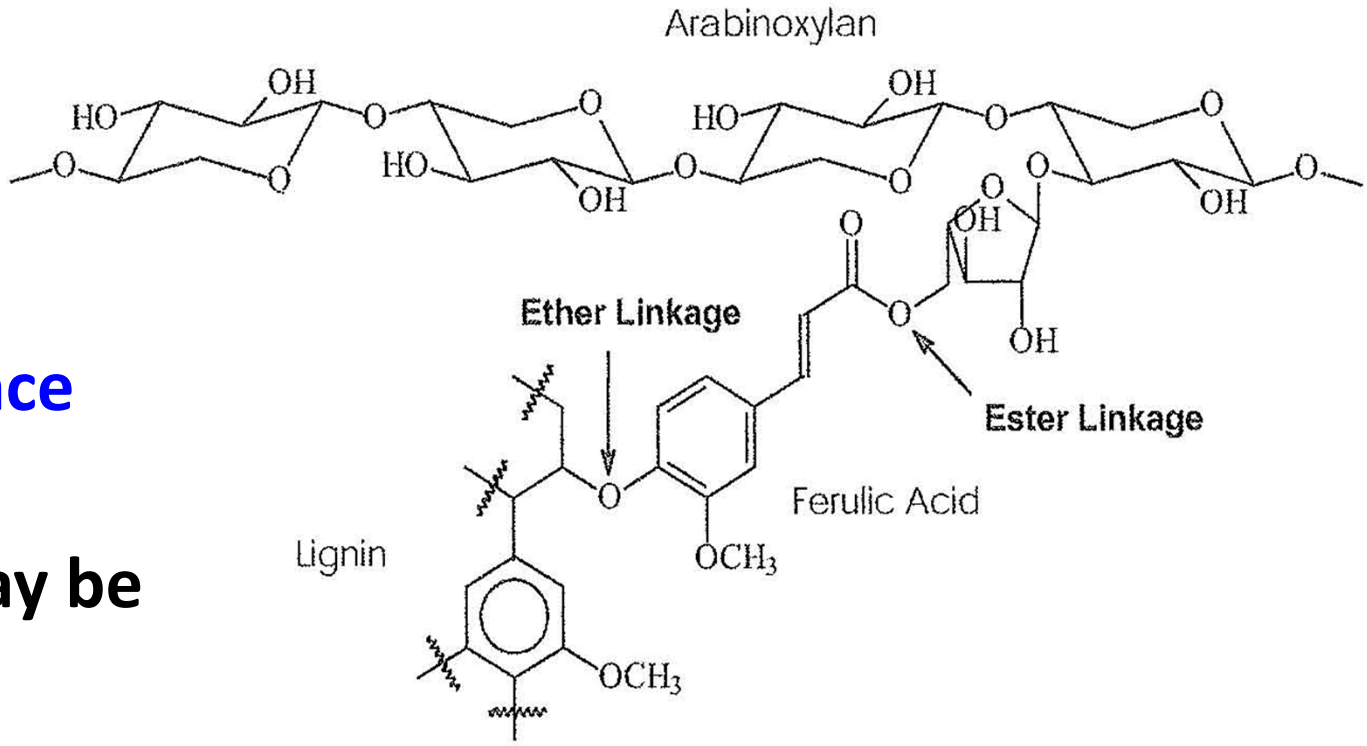
https://diagram+of+tall+building+structures

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



Lignin – Phenolic Acid – Hemicellulose Linkage

- **Ester & ether linkages to hemicellulose**
- **Steric hindrance**
- **Phenolic-CHO complexes may be toxic**



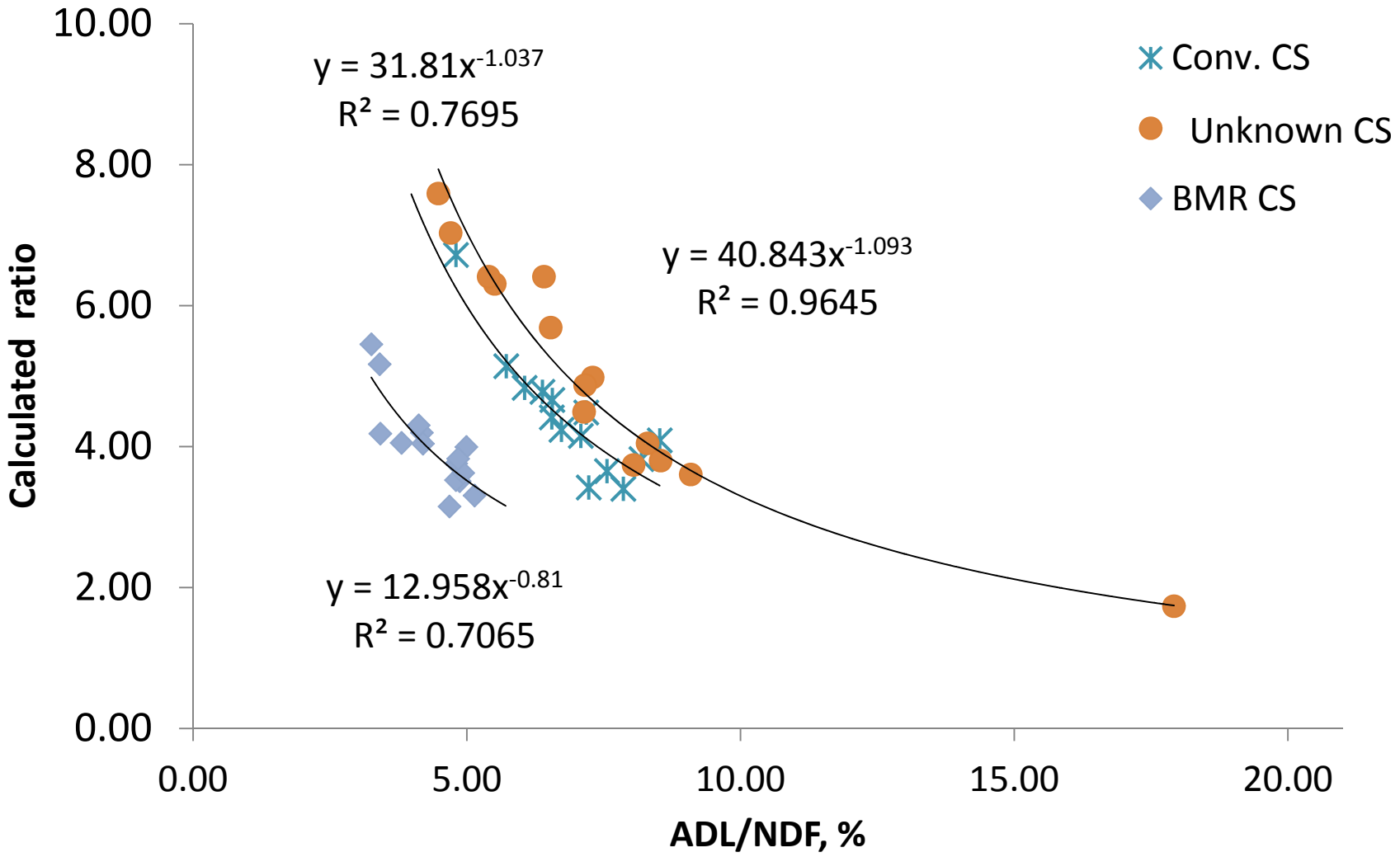
(Grabber, 2005)

Ratio of lignin to uNDF

Group	n	NDF	ADL	uNDF	Ratio (range)
		%DM	g/kg NDF		uNDF/ADL (%NDF)
Conventional C.S.	30	42.7	72.4	316.8	4.72 (1.73-7.59)
BMR C.S.	15	39.1	43.6	171.7	4.01 (3.14-5.45)
Grasses	15	47.2	62.1	222.8	3.63 (2.51-4.73)
Mature grasses	11	64.5	84.4	313.8	3.89 (2.60-5.64)
Immature grasses	13	44.1	59.3	232.2	4.16 (2.59-7.40)
Alfalfas	18	36.6	172.6	461.4	2.70 (2.43-2.95)

Raffrenato 2011

Relationships for corn silages



NDF Digestibility/Indigestibility

Weisbjerg et al. (2010) measured iNDF in legumes and grasses

- 288 h in situ,
- 12 µm porosity bags

Grasses range between 1.27-4.57 for ADL and iNDF

Legumes ranged between of 1.22-3.59 for ADL and iNDF respectively,

Corn silage example for uNDF 240 vs lignin*2.4 – 2013 corn silages

	CS 1	CS 2	CS 3	CS 4
NDF, %DM	45.4	44.5	40.3	50.2
aNDFom, %DM	44.4	43.8	38.8	49.3
Lignin, %DM	3.40	3.43	2.87	4.26
Lignin*2.4/NDF	18.4	18.7	17.9	20.7
uNDF, %NDF	11.8	10.7	10.9	14.2

27 FIELD 316 SORGHUM X SUDAN

FIBER	% NDF	% DM
ADF	56.5	34.0
aNDF		60.2
aNDFom		55.4
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin	4.95	2.98
	60.2	36.3
	74.9	45.1
uNDF (30 hr)	39.8	24.0
uNDF (240 hr)	25.1	15.1

~ 5 units

Lignin*2.4 relationship = 12.9% of NDF undigestible

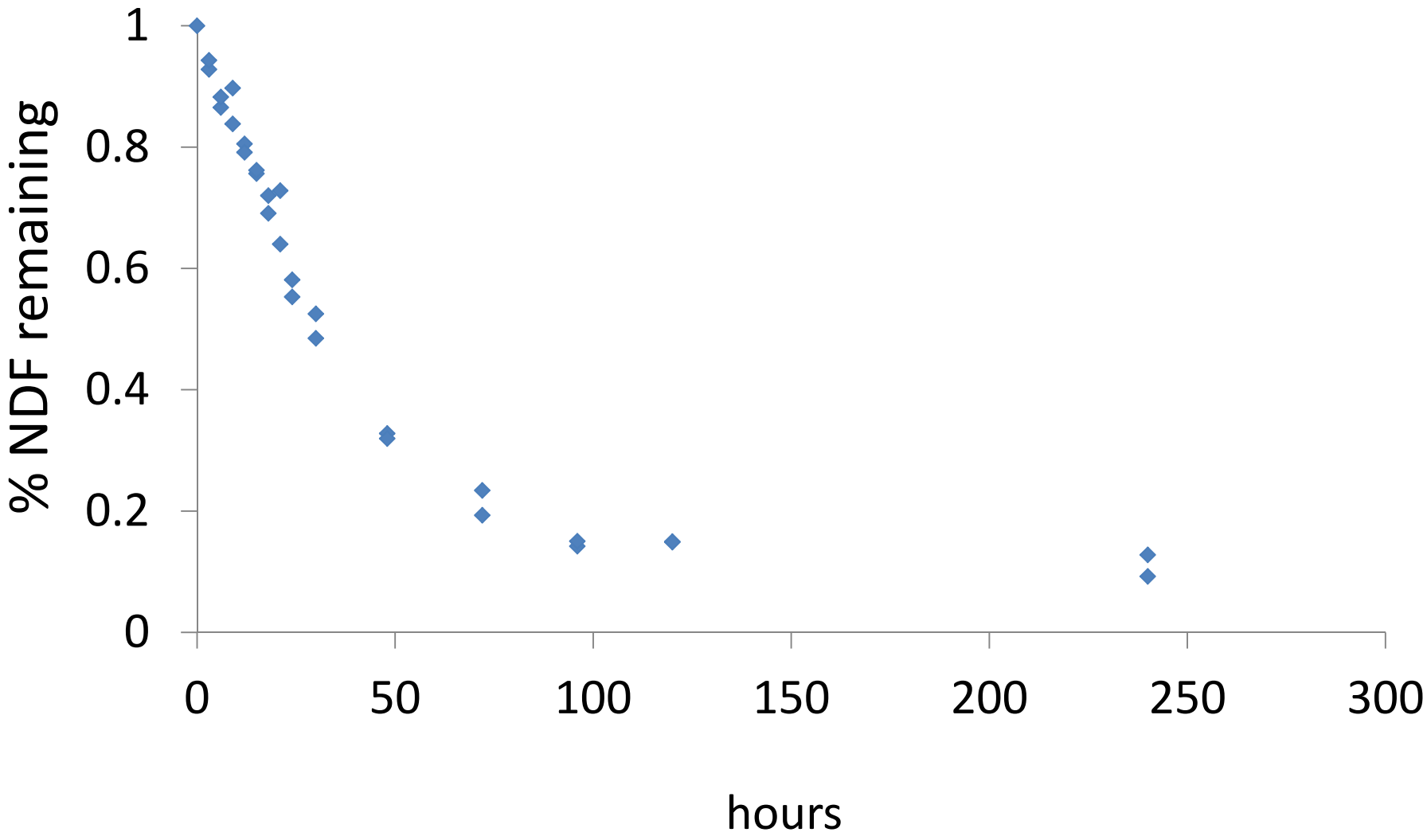
Opportunity with uNDF

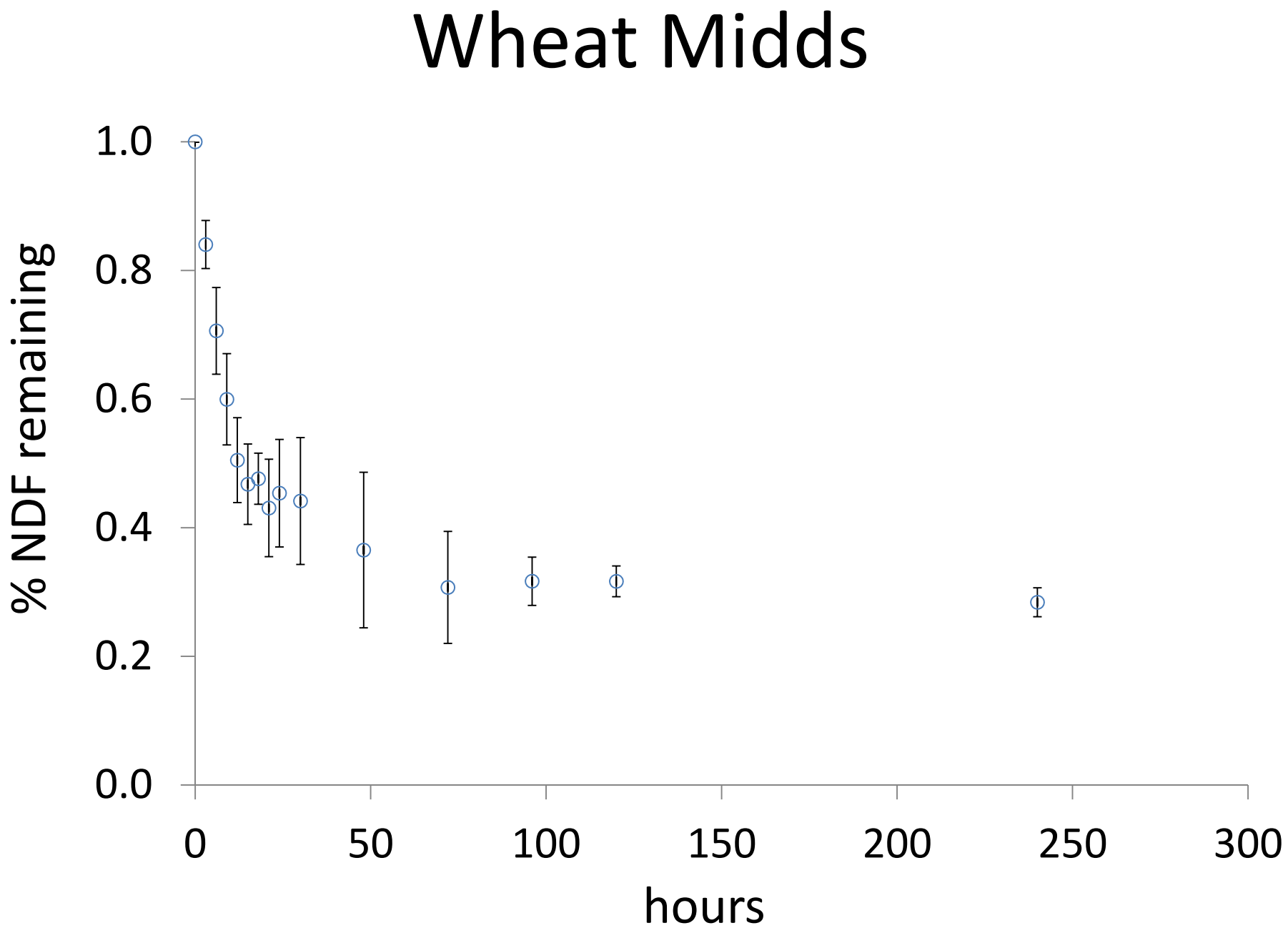
- Improve predictions of energy from forages – more biologically appropriate measurement
- Eliminate the need for ADF and lignin measurements
  - Only do ADF to get to lignin
  - Only use lignin to calculate relationships to NDF (either CNCPS approach or Weiss et al 1992)
- Helps improve predictions of intake and rumen function – microbial production, etc

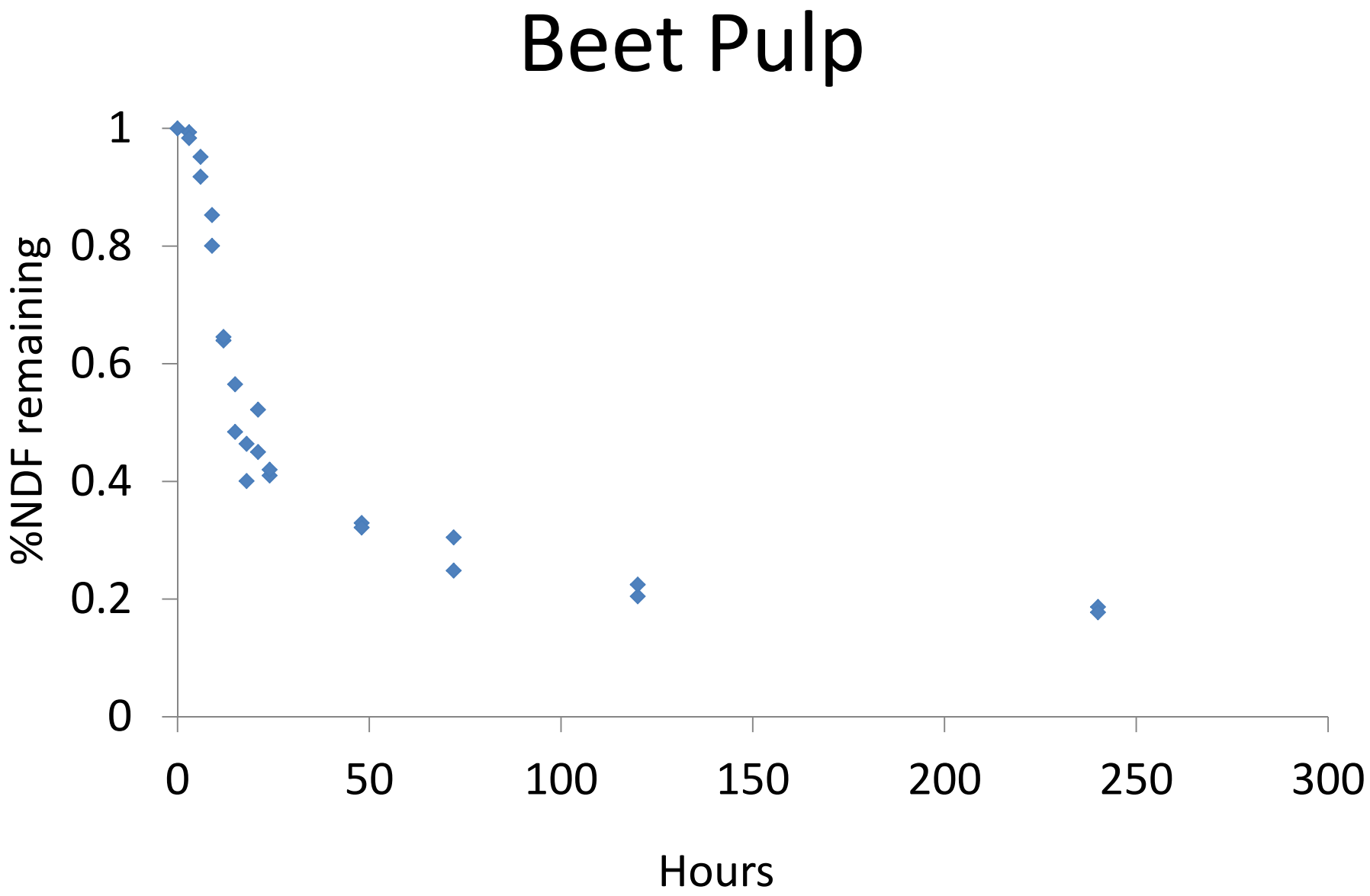
Citrus Pulp

- aNDFom: 22%
- Lignin: 2.35%
- uNDF: 1.7% (240 h NDF digestibility)
- Calculated uNDF using 2.4: 24%
- Traditional NDF kd: 9%/hr
- Dynamic single pool aNDFom kd: 6%/hr
- Dynamic aNDFom multiple pool kd:
  - P 1 (fast pool): 93% Kd 1: 7%/hr
  - P 2(slow pool) 5.3% Kd 2: 5%/hr

Corn Gluten Feed




Wheat Midds
% NDF remaining
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
hours


Beet Pulp
%NDF remaining
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
Hours

NDF pool and rate	Beet pulp	Canola	Whole cotton seed	Wheat midds	Soyhulls
uNDF, % NDF	19	26	46	29	5
2.4*lignin NDF	25.2	64	57.2	14.3	11
P 1, % NDF	71	65	34	47	77
P 2, % NDF	9	9	20	23	17
K1, %/h	12	6	7	16	4
K2, %/h	1	1	1	3	4

Composition of diets used in uNDF study at Miner Institute.

	Diet			
Ingredient % of ration DM	LF-LD (Low CS)	HF-LD (High CS)	LF-HD (Low BMR)	HF-HD (High BMR)
Conventional corn silage	39.2	54.9	---	---
Brown midrib corn silage	---	---	36.1	50.2
Hay crop silage	13.4	13.4	13.3	13.3
Corn meal	17.3	1.6	20.4	6.3
Grain mix	30.1	30.1	30.2	30.2
Chemical composition				
Crude protein, % of DM	17.0	17.0	16.7	16.7
NDF,% of DM	32.1	35.6	31.5	35.1
Starch, % of DM	28.0	21.2	27.8	23.8
24-h NDF digestibility, %	56.3	54.0	62.0	60.3
peNDF, % of DM	17.3	23.1	18.5	21.5

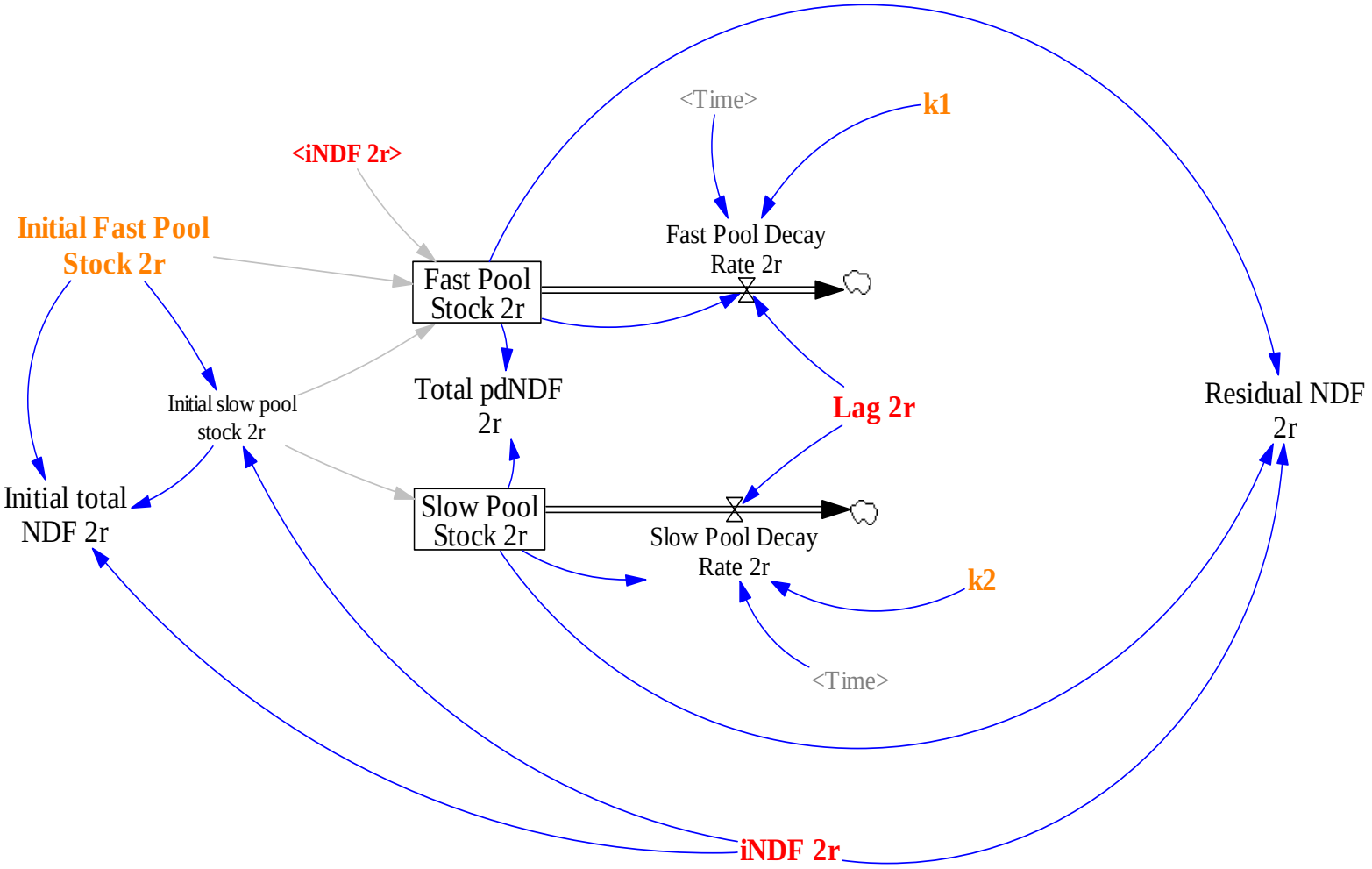
NDF and uNDF composition of forages and diets fed in Miner study.

Item	BMR CS	Conv CS	HCS	LF-LD	HF-LD	LF-HD	HF-HD
aNDFom, % of DM	34.8	36.1	46.2	30.8	33.7	30.7	33.5
$NDFD_{240m}$, % of NDF	62.1	48.6	57.7	…	…	…	…
$uNDF_{240m}$, % of NDF	21.9	30.5	30.3	26.7	28.5	22.5	22.6
$uNDF_{240m}$, % of DM	7.6	11.0	14.0	8.2	9.6	6.9	7.6

Intake of NDF and uNDF and rumen fill for Miner study.

Item	LF-LD	HF-LD	LF-HD	HF-HD
NDF_{om} intake				
kg/d	8.87	8.95	8.48	9.88
% of BW	1.32	1.33	1.27	1.47
Rumen NDF_{om}				
kg	8.50	8.58	7.82	8.48
% of BW	1.27	1.28	1.17	1.27
$uNDF_{240om}$ intake				
kg/d	2.39	2.63	2.03	2.21
% of BW	0.36	0.39	0.30	0.33
Rumen $uNDF_{240om}$				
Kg	3.82	4.16	3.20	3.46
% of BW	0.57	0.62	0.48	0.52
Fecal uNDF, kg/d	2.41	2.64	2.04	2.24
Ratio rumen/intake uNDF	**1.60**	**1.58**	**1.58**	**1.57**

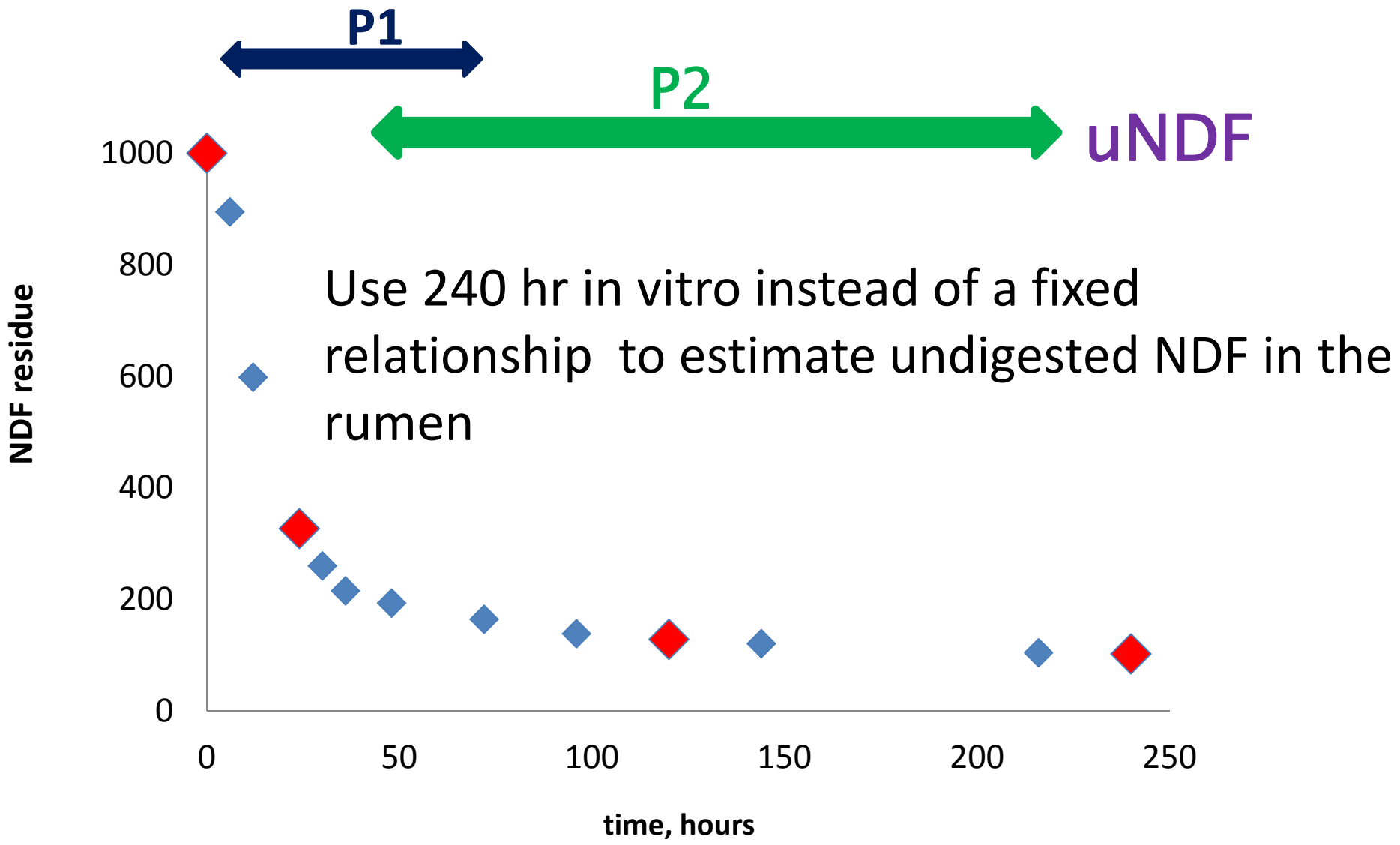
Calculation of rates and pool sizes using in-vitro 30, 120 and 240 hr NDFD data



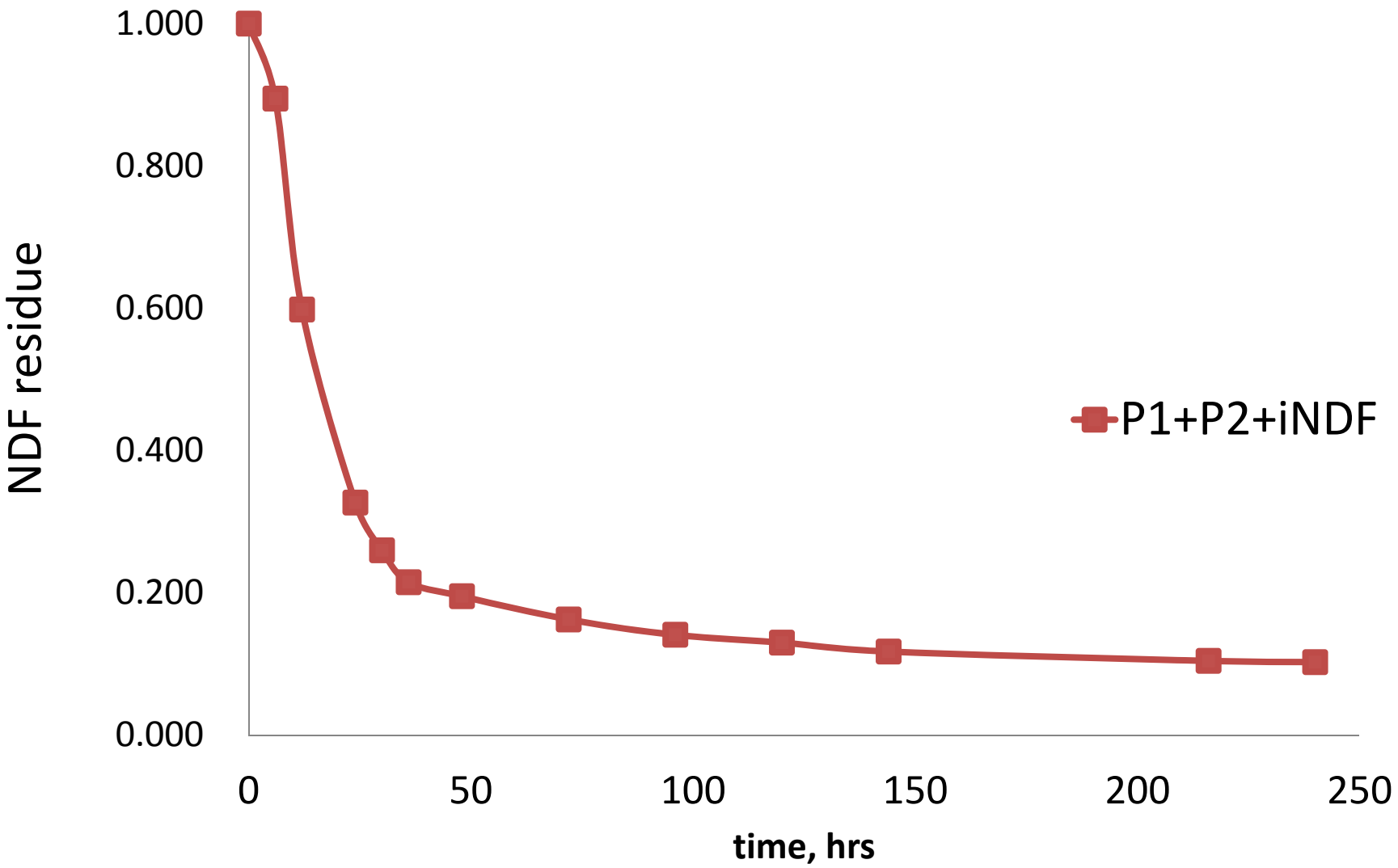
Parameters in orange are the those to be optimized

Raffrenato et al. 2011

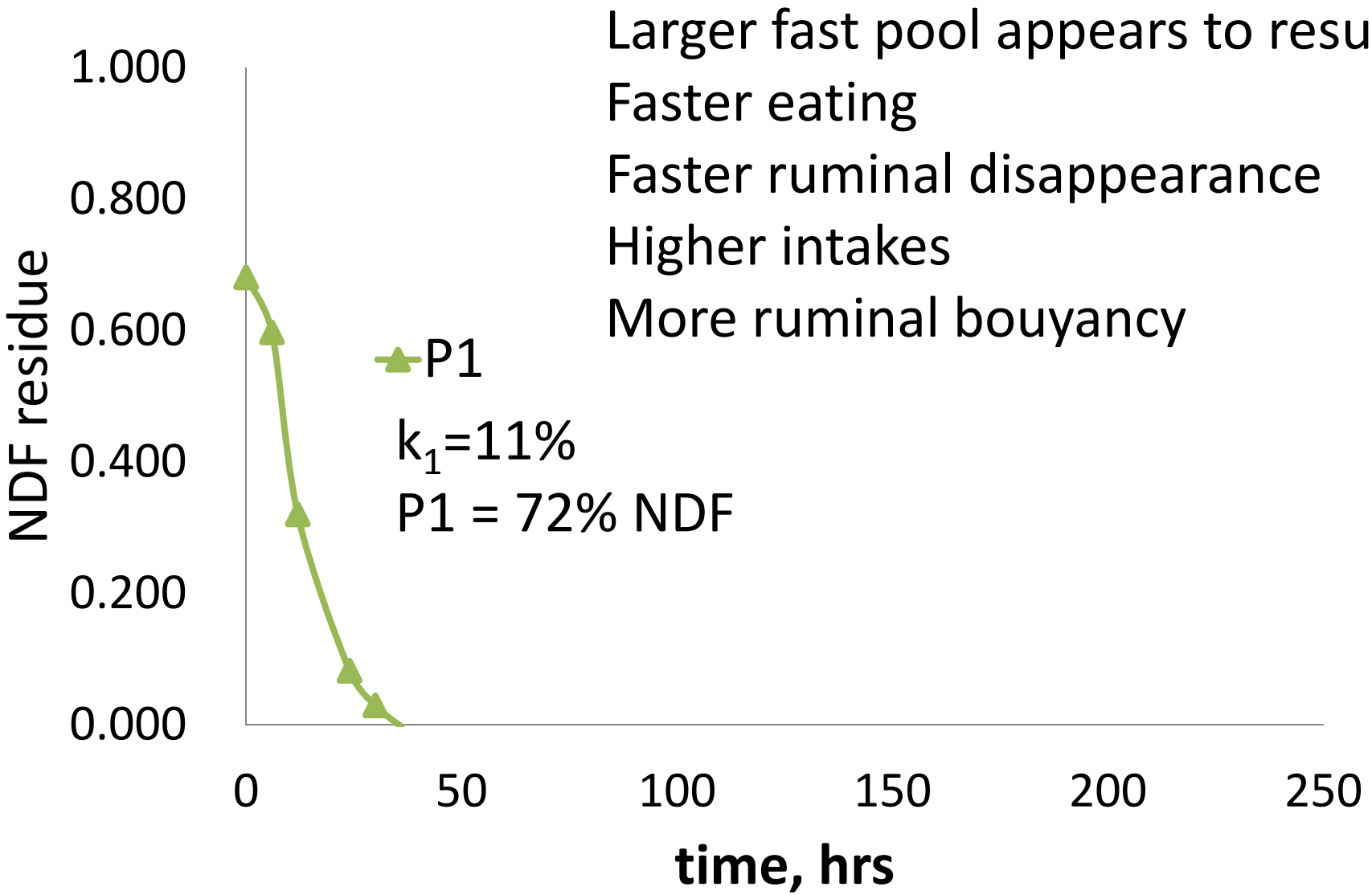
Corn silage: 2 time-points + 240 hours



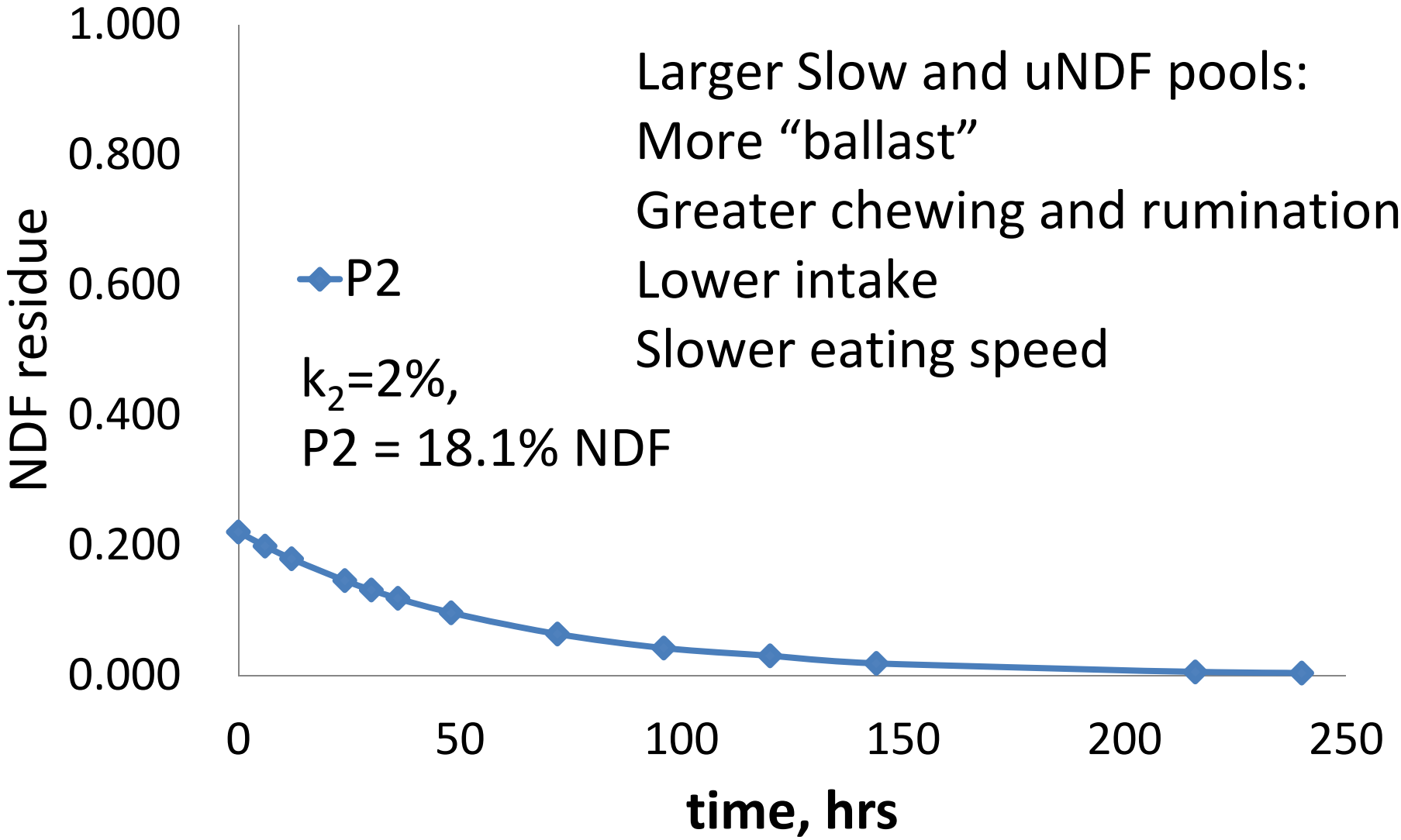
Corn silage example: $NDF_{digestibility}$



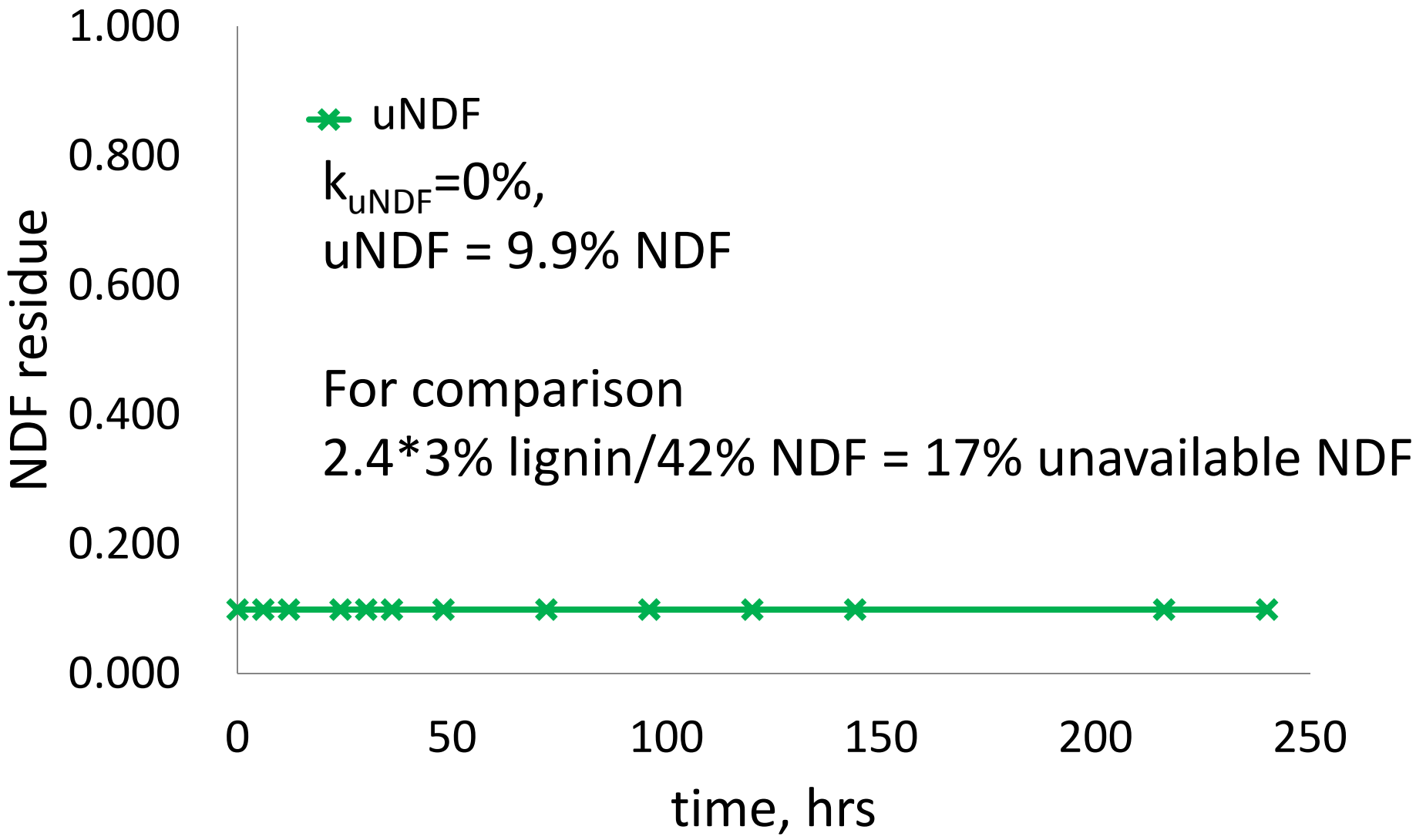
Corn silage example: fast pool



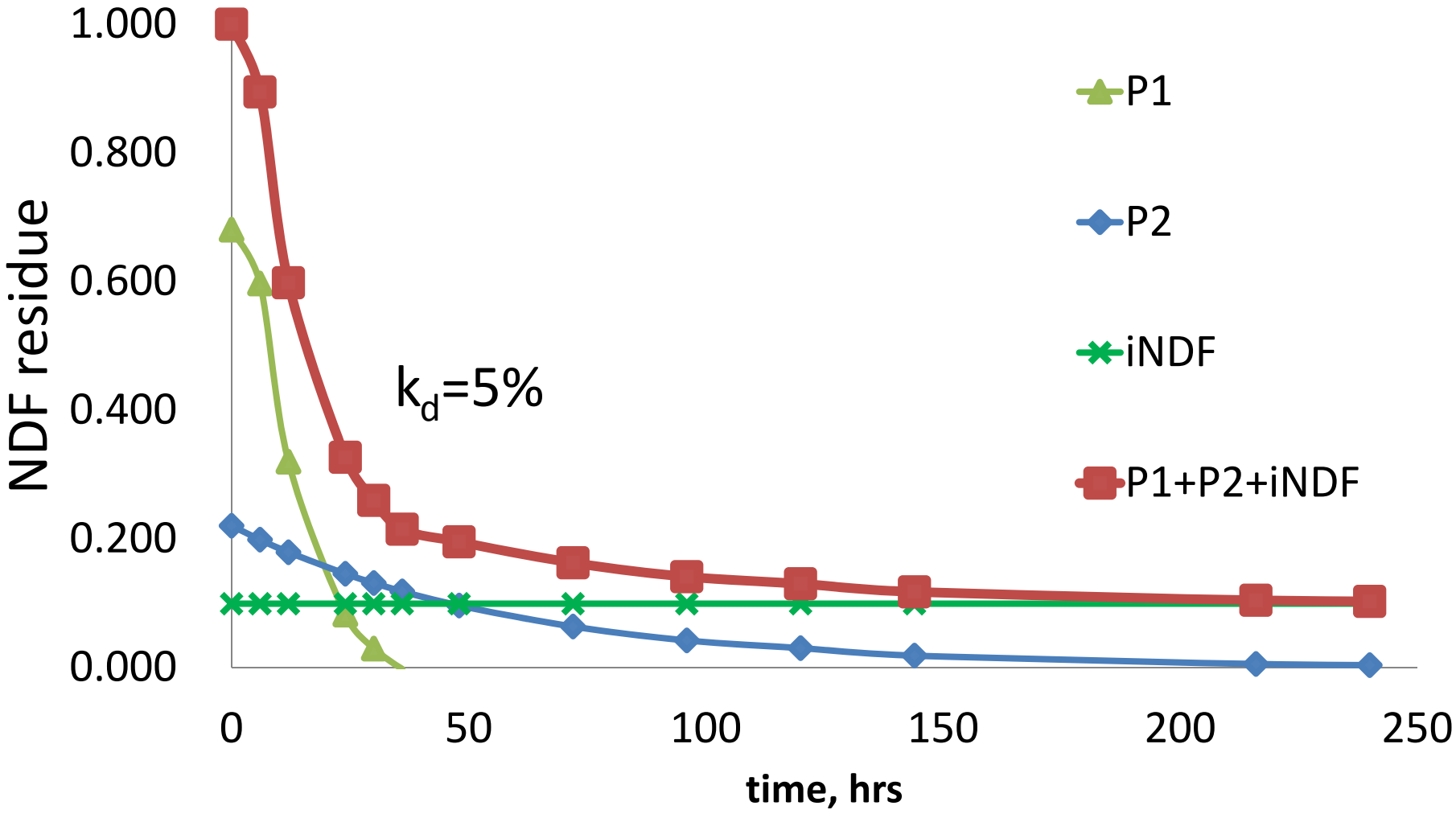
Corn silage example: slow pool



Corn silage example: iNDF



Corn silage example: P1+P2+iNDF



Conclusions and implications

- The use of 240 hr NDFD better describes the undigestibility of the forage for use in cattle
- A better description of NDF undigestibility can be implemented by commercial laboratories – especially for undigested NDF – will have to build new NIR calibrations
- Working to develop a larger data set to explain the variation in NDF pool sizes and rates for all NDF containing feeds
  - Within forage group information is linked to agronomic and environmental conditions but not well described

Opportunity with uNDF

- Improve predictions of energy from forages – more biologically appropriate measurement
- Eliminate the need for ADF and lignin measurements
  - Only do ADF to get to lignin
  - Only use lignin to calculate relationships to NDF (either CNCPS approach or Weiss et al 1992)
- Helps improve predictions of intake and rumen function – microbial production, etc

Thank you for your attention.

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