Fiber Digestibility, Forage Fragility, and Chewing Response in Dairy Cattle: Update 2009

Bucknell Nutrition Conference 2009
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Overview

- Theory of peNDF: Mertens
- Fragility Concept: Ball Mill
- Hay Trial: CNC 2008
- Renaissance Field Samples: Fragility
- Supplemental Fiber: Hay vs Straw ADM 2009

WH Miner research focus: NDF digestibility and chewing behavior

- NDFD
  - In vitro: Ankom Daisy
  - Phenolics: ester & ether linkages
- Particle size
  - peNDF & Z Box
- Chewing Behavior
  - Cow watch
- Forage Fragility
  - Method
  - Relation to chewing

Introduction

- peNDF system: assumes that all NDF stimulates equal chewing response
  - Based only on particle size
- Not all NDF is the same
  - Oat straw vs alfalfa hay: elicits ~2x chewing
  - BMR CS vs non-BMR CS: fragile
- Forage "fragility" may explain some of the variation in chewing not explained by particle size
- Related to lignin & digestibility, cell wall thickness
- Are NDFd, forage fragility & chewing related?

Chewing and NDF Source; Similar Particle Size (Mertens, 1997)

Feed	NDF[1] % of DM	Total Chewing Activity (min/kg of DM)	Total Chewing Activity (min/kg of NDF)
Alfalfa	49	61	125
Dried grass	51	63	123
Ryegrass	65	90	139
Grass	65	103	158
Ryegrass	68	104	152
Grass	65	107	165
Oat straw	78	163	209
Oat straw	79	143	181
Oat straw	84	164	195

Why Differences in Chewing Response?

- Forage Fragility Concept
  - Forages differ in fiber strength, or toughness, and resistance to physical breakdown during chewing
    - Particles differ in their diameter
    - Particles differ in lignin & lignin composition
    - Cell wall physiology
    - Particles differ in moisture
    - Particles differ in digestibility

Introduction

- How to measure forage fragility?
  - Artificial mastication (1964)
  - Animal behavior watch: visual observation
  - Comminution energy required to grind
  - Shear force energy required to cut
  - Ball mill: particle size reduction index
    - Generate an adjustment factor for peNDF
- A need for a method of forage analysis that better predicts chewing and rumen health

Materials and Methods

- Equipment
  - Mill
  - Jars: 13.6 L, 8.15 L & 5.5 L
  - Ceramic cylinders (balls)
  - RoTap: dry vertical shake sieve apparatus

Corn silage ball milled for 15 min to 6 hr (Cotanch et al., 2007)

- Ball mill with ceramic balls mimics chewing action (Jim Welch, unpublished data)

Measurement of fragility

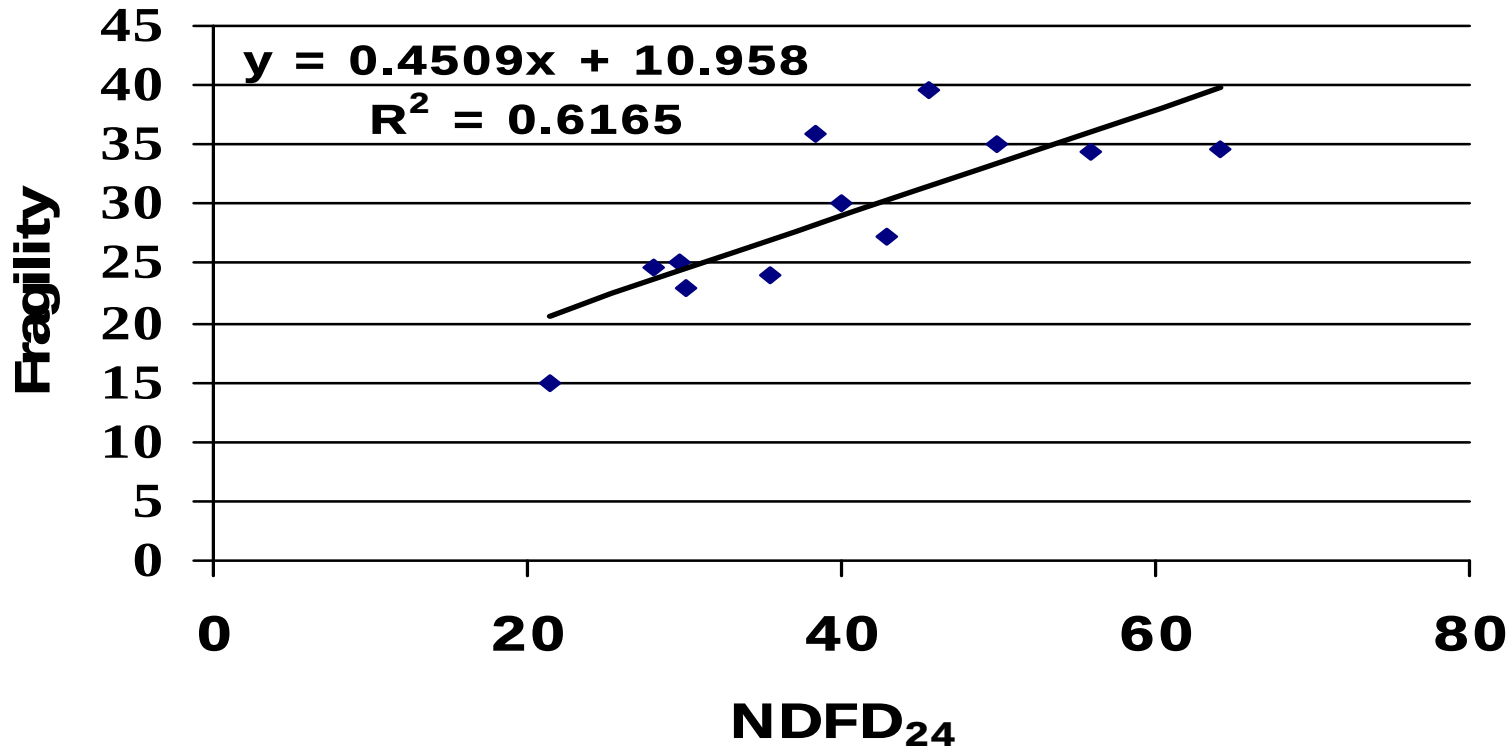
- Initial pef (pef_i) determined using dry vertical sieving
- Forage particles collected from sieves and recombined, then subjected to 15 min of ball milling in 5.5-L ceramic jar with 2.6 L of ceramic disks and rolled at 80 rpm
  - modified from original 6-h procedure
- Milled forage collected from the ball mill jar and media for determination of pef_{BM15}
- Fragility determined as Δpef
  - $(pef_i - pef_{BM15})/pef_i \times 100\%$
- Fragility value of 100% = highly fragile forage, complete reduction of particle size to less than 1.18 mm.
- Fragility value of 0 = very tough forage, no reduction in particle size upon ball milling, $pef_i = pef_{BM15}$

The pef values of original sample and ball milled sample with percentage decrease in pef value (fragility)

Forage	$NDFD_{24}$	Original pef	30-min BM pef	BM pef as % of original pef	% Change
GS Bunk ½ 1st cut	45.6	61.1	36.9	60.4	-39.6
GS Bunk 3 1st cut	55.8	60.1	39.3	65.4	-34.5
CS Bunk 4	35.4	88.9	67.5	75.9	-24.1
CS Bunk 7	42.8	92.0	67.0	72.8	-27.2
LS Agbag 3rd cut	64.2	73.6	48.1	65.4	-34.6
Alfalfa Hay Stems	28.1	95.0	71.6	75.4	-24.6
Alfalfa Hay Leaves	47.6	41.1	13.0	31.6	-68.5
Grass Hay Ballard 1st cut	29.6	84.1	63.1	75.0	-25.0
Wheat Straw	21.5	99.7	84.8	85.1	-14.9

(Cotanch et al., 2007)

Forage fragility as measured by % change in pef plotted by $NDFd_{24}$



(Cotanch et al., 2007)

2008 Hay trial with pregnant heifers

- Objective
  - Determine the relationship between forage fragility and digestibility measured using a ball milling method and cow chewing response for four grasses representing a wide range in fragility and NDF digestibility

Procedures - 1

- 16 gravid, nulliparous Holstein heifers
  - 18.5 months of age, 149.5 days-carried-calf, 4.0 BCS
- Housed in tie stall with feed boxes
- 4 x 4 Latin square with 4 diets
  - 7-d periods: 3 d adaptation, 4 d collection
  - Test Hay *ad lib* + 1.8 kg/cow/day pelleted 27% CP grain mix

Procedures - 2

- Each grass hay was chopped using Haybuster model H-1100 to similar particle size
- Hays A and B: 1st cutting, 2007
- Hays C and D: 2nd cutting, 2007
- Hays analyzed for standard CPM nutrient profile
- In vitro NDF digestibility measured at 24 and 120 h

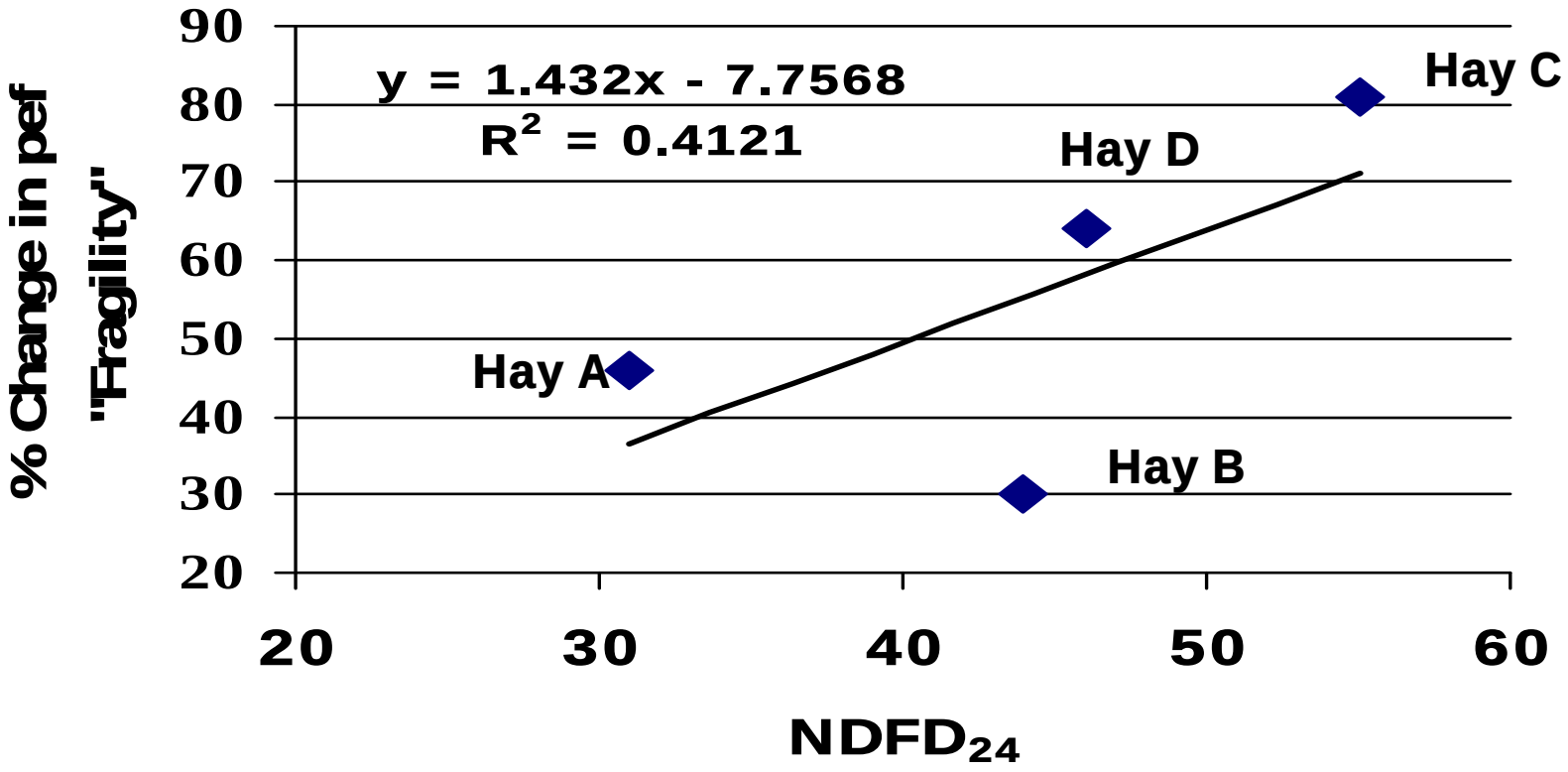
Composition of test hays

Item	Hay A	Hay B	Hay C	Hay D	Grain
CP, %	8.1	7.8	12.1	10.4	27.2
NDF, %	66.1	70.7	58.6	59.2	26.5
ADL, %	6.5	5.6	4.1	4.5	3.1
Starch, %	1.8	1.9	1.9	1.7	29.9
Sugar, %	8.0	8.3	9.5	15.6	6.0

Digestibility and fragility of test hays

Item	Hay A	Hay B	Hay C	Hay D
$IVNDFd_{24h}$, % NDF	31.4	43.7	54.8	47.3
Fragility	46.2	30.0	80.7	63.9

$NDFd_{24}$ versus fragility for the test grass hays used in the study



Particle size of grass hays

Item	Hay A	Hay B	Hay C	Hay D
PSPS, % as-fed				
>19.0 mm	28.0	19.9	27.2	31.3
8.0 to 19.0 mm	27.5	31.0	21.9	22.9
<8.0 mm	44.6	49.1	50.9	45.8
$pef_{1.18\text{-mm}}$	0.49	0.45	0.36	0.46
$pef_{3.35\text{-mm}}$	0.13	0.13	0.11	0.15
$pef_{Z\text{-box } 4.76 \text{ mm}}$	0.51	0.35	0.46	0.46
$peNDF_{1.18\text{-mm}}$	33.5	32.2	21.4	28.9
$peNDF_{3.35\text{-mm}}$	9.0	9.2	6.6	9.3

Results: Intake of grass hays

	Hay					*P*-value		
	A	B	C	D	SE	Diet	Per	Rep
DMI, kg/d	9.5^{d}	9.9^{c}	11.3^{a}	10.8^{b}	0.10	<.001	<.001	0.22
DMI, % BW	1.73^{d}	1.81^{c}	2.04^{a}	1.96^{b}	0.04	<.001	<.001	0.13
NDFi, kg/d	**5.40^{b}**	5.96^{a}	5.84^{a}	5.82^{a}	0.12	<.001	<.001	0.31
NDFi, % BW	**0.98^{b}**	1.08^{a}	1.05^{a}	1.05^{a}	0.03	<.001	<.001	0.24
BW, kg	572	570	573	570	11	0.340	<.001	0.09

Results: Chewing response

	Hay					*P*-value		
Item	**A**	**B**	**C**	**D**	**SE**	**Diet**	**Per**	**Rep**
Total chewing								
min/d	790	765	756	772	15	0.095	0.022	0.42
min/kg NDFi	**149**[a]	130[b]	130[b]	132[b]	3	<.001	<.001	0.14
Eating								
min/d	267	278	261	275	10	0.244	0.273	0.59
min/kg NDFi	50[a]	48[a]	**45**[b]	47[a]	2	0.018	0.103	0.43
Ruminating								
min/d	523[a]	487[b]	495[ab]	497[ab]	10	0.011	0.034	0.62
min/kg NDFi	**99**[a]	83[b]	85[b]	85[b]	2	<.001	<.001	0.15

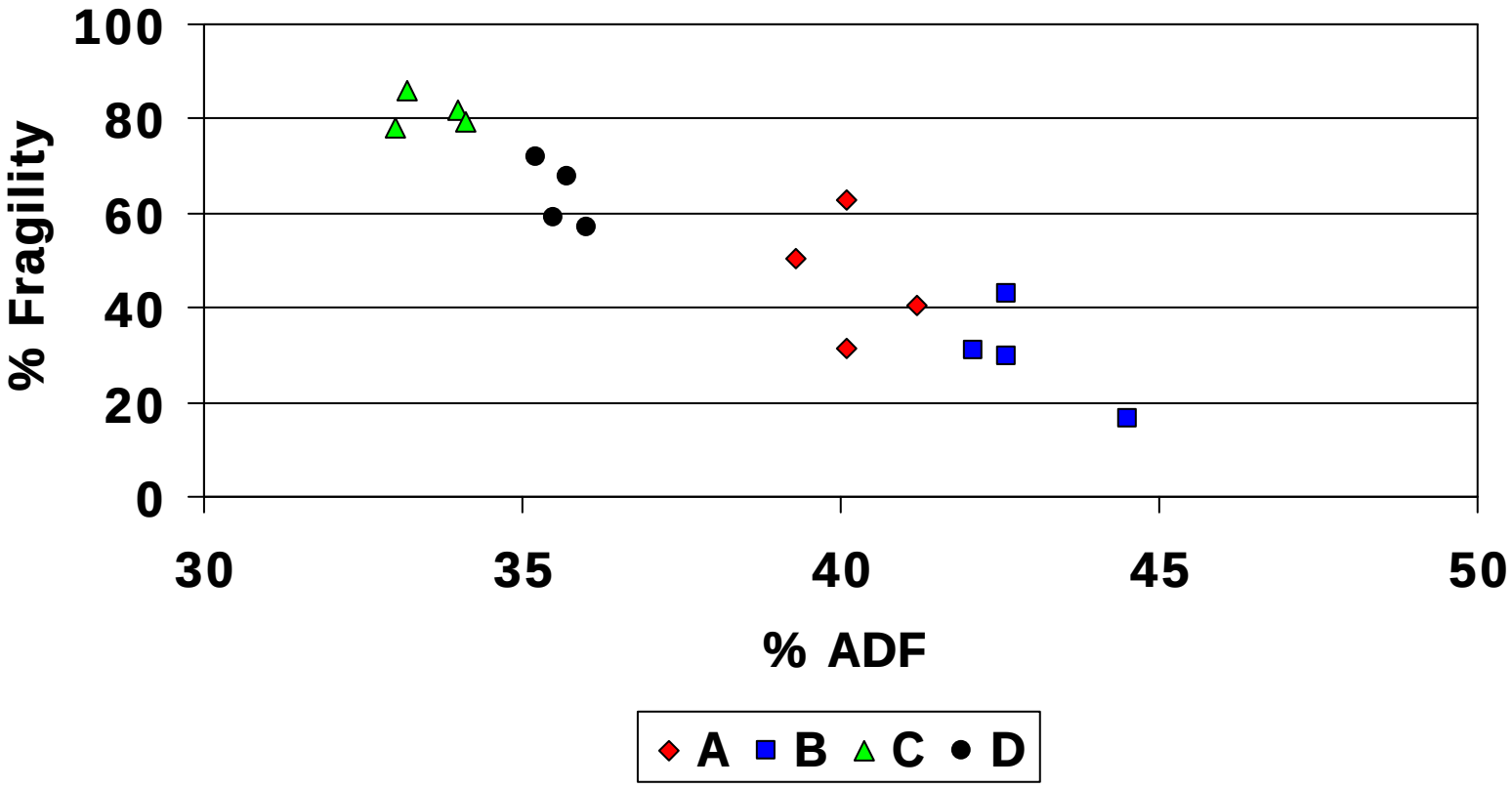
Summary of responses

- Hay A versus Hay C
  - Low fragility, low NDFD versus high fragility and NDFd
  - NDF (66 vs 59), ADL (6.5 vs 4.5)
  - 24-h NDFD lower (31 vs 55)
  - Fragility lower (46 vs 81)
  - pef similar, perhaps lower for Hay C depending on technique (0.49 vs 0.36)
  - Ruminating response greater
    - Fragility: maybe
    - NDFD: maybe

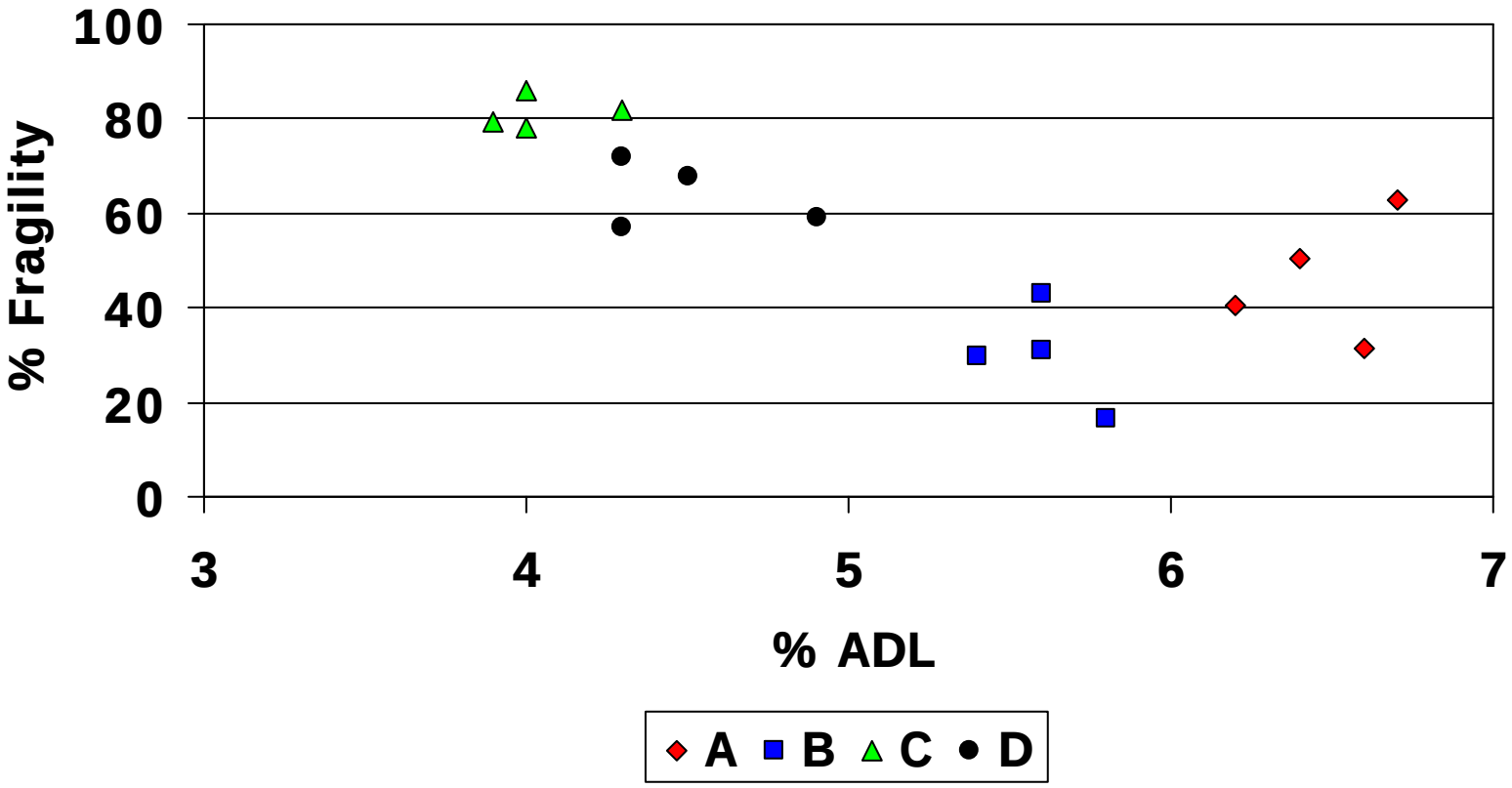
Summary of responses

- Hay B versus Hay D
  - medium NDFD with low and high fragility
  - NDF (71 vs 59) and ADL (5.6 vs 4.5)
  - 24-h NDFD similar (44 vs 47)
  - Fragility lower (30 vs 64)
  - pef similar (0.45 vs 0.46)
  - Ruminating response similar
    - Fragility: ???
    - NDFd: maybe

Fragility in relation to acid detergent fiber



Fragility in relation to acid detergent lignin



Hay Trial Conclusions

- With these grasses, we observed significant differences in eating and ruminating response that appeared to be partly explainable by differences in NDFD & fragility
- It may be possible to predict chewing response using fragility or NDFD

Renaissance Fragility Field Samples 2008

- Field Samples from Renaissance Feed Reps (Nov 08-Apr09)
  - PSPS
  - Z Box pef
  - NDFD24
  - Fragility
- Broaden sample base for testing NDFD x Fragility relationship

Renaissance Fragility Field Samples PSPS and Z Box: Corn silage

Sample	Type	DM, %	pef_{Zbox}	pef_{RoTap}	$peNDF_{Zbox}$	PSPS		
						Top	Mid	Pan
BMR CS U. Delaware	BMRCS	45.6	0.800	0.846	30.6	2.4	56.1	41.5
CS BMR Bunk 1 Sean Jones	BMRCS	31.4	0.910	0.915	35.3	8.3	72.8	19.0
CS BMR Bunk 7 Front Mycogen F2F797 Sean Jones	BMRCS	34.1	0.893	0.890	36.9	5.3	72.5	22.2
CS BMR Bunk 5	BMRCS	34.3	0.930	0.940	33.5	2.6	78.4	19.0
CS BMR Trench 2 Sean Jones	BMRCS	32.9	0.925	0.910	34.6	6.9	76.8	16.3
Udel BMRCS Buchneri 500	BMRCS	38.2	0.813	0.837	33.3	1.4	60.9	37.6
Udel BMRCS - no treatment	BMRCS	40.5	0.856	0.850	31.6	2.9	59.0	38.1
BMR CS Matt Toms	BMRCS	36.4	0.924	0.923	37.2	8.3	74.6	17.1
CS Conv. Silo 3 U. Delaware	CS	38.9	0.749	0.700	27.0	5.4	54.3	40.4
CS Bunk 3 Sean Jones	CS	33.1	0.872	0.861	34.7	2.8	73.4	23.8
CS Stack	CS	35.0	0.890	0.907	31.9	5.5	72.4	22.0
CS White Post Dairy	CS	27.6	.	0.921	.	.	.	.
CS Sweet Corn Silage Sean Jones	CS	25.0	0.948	0.954	55.7	67.9	18.7	13.5
CS Conv Trench 2 Sean Jones	CS	32.0	0.927	0.910	34.7	3.0	80.3	16.7
CS 11 CFT Treated Silo 3 Sean Jones	CS	33.1	0.895	0.879	37.3	5.9	72.5	21.6

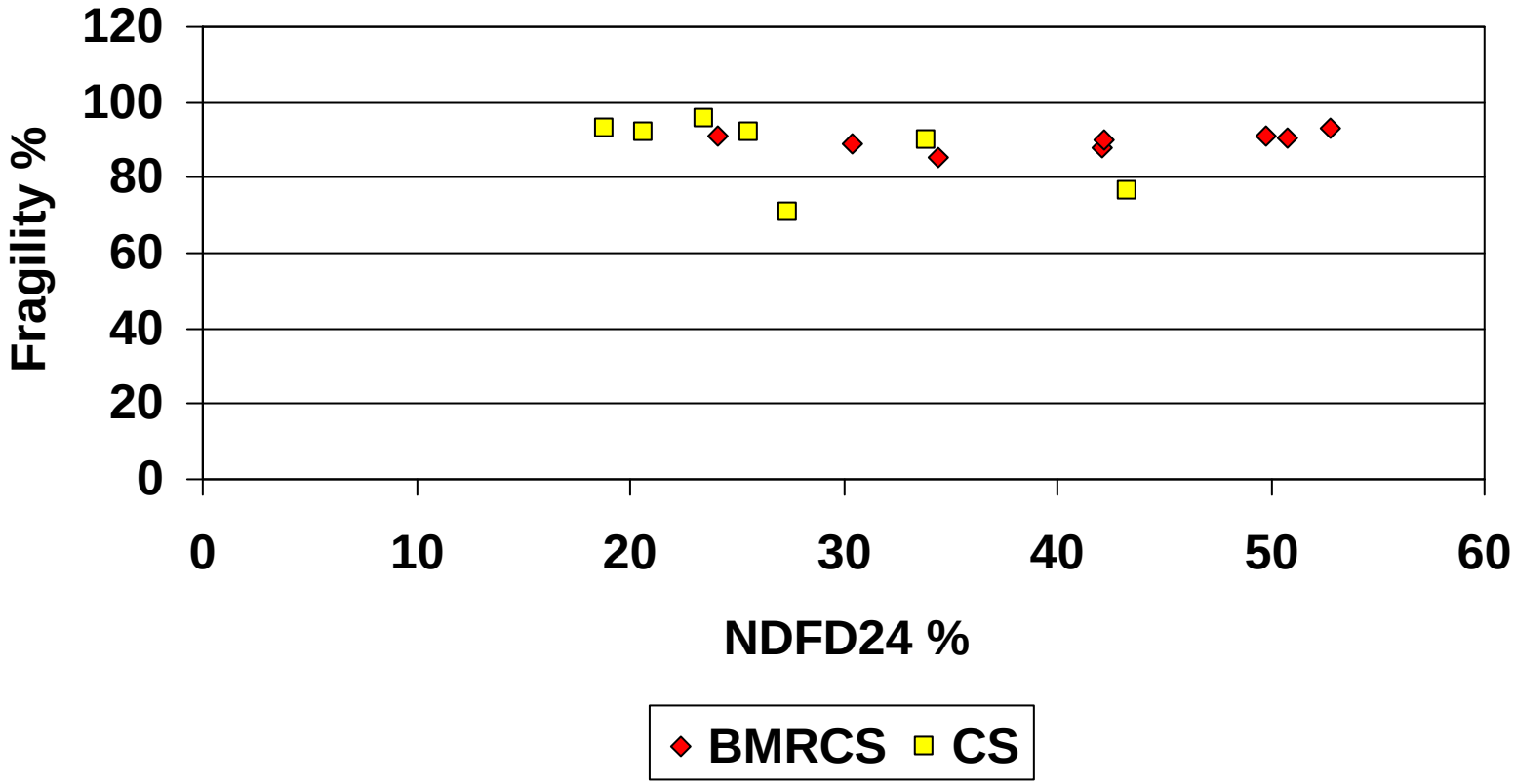
Renaissance Fragility Field Samples PSPS and Z Box: Haylage and SGS

Sample	Type	DM, %	pef_{Zbox}	pef_{RoTap}	$peNDF_{Zbox}$	PSPS		
						Top	Mid	Pan
HCS 1st cut Leg U. Deleware	HCS	29.0	0.791	0.868	35.1	38.2	42.0	19.8
HCS 1st cut Bunk Brooks	HCS	37.7	0.727	0.801	39.4	22.6	55.6	21.8
HCS Bunk 3 1st cut	HCS	34.8	0.752	0.717	44.1	42.3	41.1	16.6
Alfalfa Haylage 1st cut '08 Ray Bovic	HCS	46.7	0.727	0.799	24.6	20.6	48.8	30.6
Clover Mix Silage Stetanak OH	HCS	45.8	0.700	0.888	36.4	9.7	49.1	41.2
Alf Haylage Dave Gruenbaum	HCS	32.7	0.751	0.846	38.6	13.4	60.6	26.0
Alfafla Haylage Dean Sharp	HCS	46.6	0.817	0.899	27.9	33.0	45.6	21.4
Haylage '08 20x70 Harvestor	HCS	54.3	0.670	0.692	32.5	18.5	41.6	39.9
Haylage 20x70 Concrete silo Bruce Wolf	HCS	35.9	0.703	0.795	31.7	8.7	55.7	35.6
GS Agbag C8 2nd cut 7/15/08	HCS	44.7	0.817	0.866	44.8	34.5	47.7	17.8
SGS Bunk 4 Sean Jones	SGS	28.3	0.950	0.921	54.2	39.4	51.7	8.9
Triticale Silage Bender Dairy	SGS	37.1	.	0.867	.	.	.	.
SGS Barley Sean Jnes	SGS	27.6	0.901	0.935	51.4	54.7	37.7	7.5
Straw Wheat HB 3"	Straw	87.8	0.537	0.742	43.8	21.6	35.6	42.9
TMR U. Delaware	TMR	55.1	0.499	0.527	15.6	3.6	34.9	61.5

Renaissance Fragility Field Samples NDF, NDFD24 and Fragility: Corn silage

Sample	Type	DM, %	NDF	ADF	ADL	Ash	$NDFD_{24}$	Fragility
BMR CS U. Delaware	BMRCS	45.6	38.2	20.9	1.9	3.2	34.4	85.6
CS BMR Bunk 1 Sean Jones	BMRCS	31.4	38.8	23.2	3.2	3.8	24.1	91.0
CS BMR Bunk 7 Front Mycogen F2F797 Sean Jones	BMRCS	34.1	41.3	23.6	2.2	4.1	42.1	88.1
CS BMR Bunk 5	BMRCS	34.3	36.1	21.7	1.6	2.5	50.8	90.3
CS BMR Trench 2 Sean Jones	BMRCS	32.9	37.4	22.6	2.8	3.8	30.4	89.2
Udel BMRCS Buchneri 500	BMRCS	38.2	40.9	24.2	1.9	3.1	49.8	90.8
Udel BMRCS - no treatment	BMRCS	40.5	37.0	21.7	1.8	3.2	42.2	90.1
BMR CS Matt Toms	BMRCS	36.4	40.2	24.3	1.5	3.5	52.8	92.9
CS Conv. Silo 3 U. Delaware	CS	38.9	36.0	21.7	3.0	3.1	20.6	92.0
CS Bunk 3 Sean Jones	CS	33.1	39.8	24.3	3.2	3.4	18.8	93.1
CS Stack	CS	35.0	35.8	23.0	3.6	3.3	33.9	89.8
CS White Post Dairy	CS	27.6	47.0	28.8	4.0	1.5	27.4	71.1
CS Sweet Corn Silage Sean Jones	CS	25.0	58.7	31.6	2.6	2.7	43.3	76.5
CS Conv Trench 2 Sean Jones	CS	32.0	37.5	23.5	3.2	3.8	25.6	92.3
CS 11 CFT Treated Silo 3 Sean Jones	CS	33.1	41.7	25.5	3.42	4.52	23.5	95.6

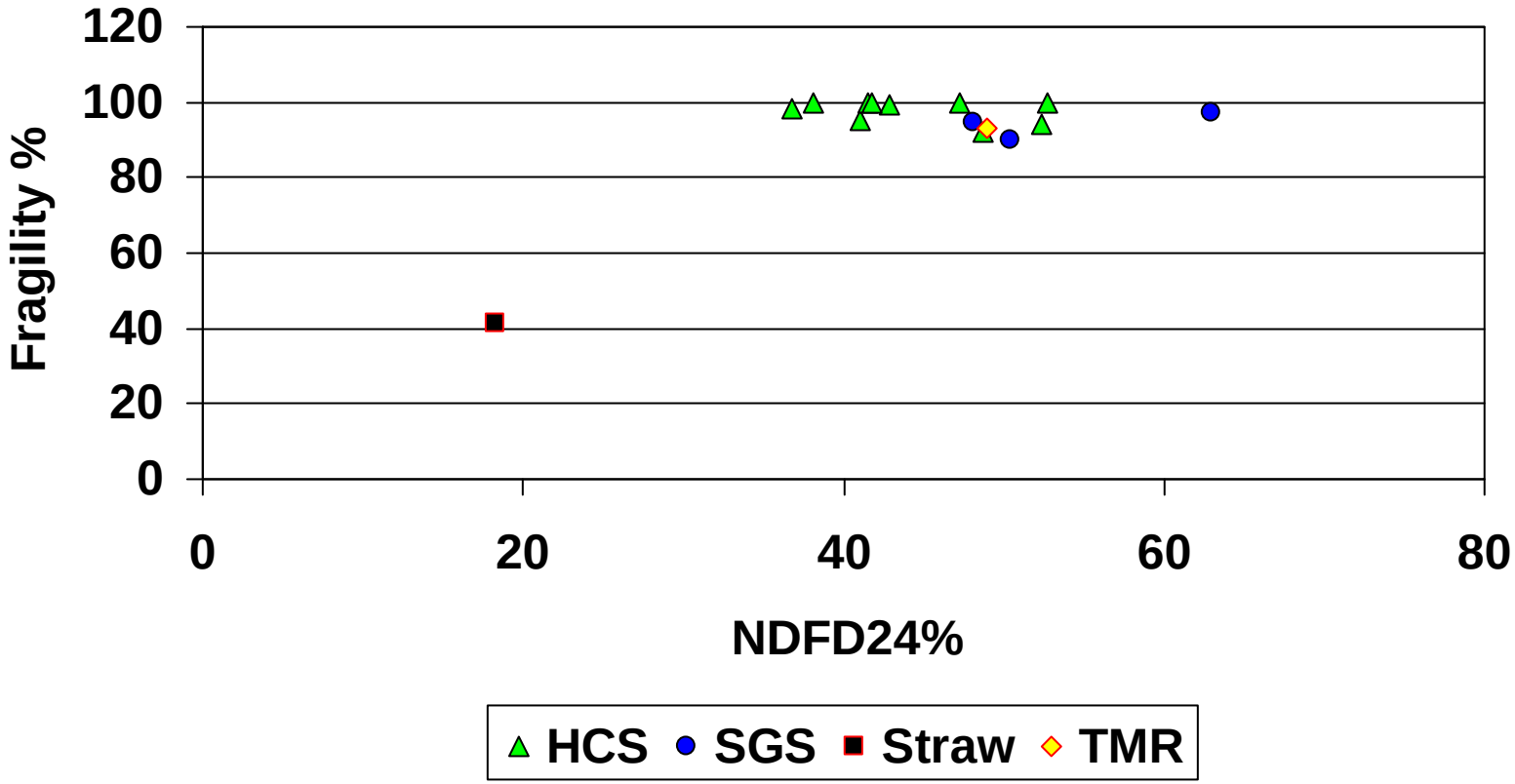
Renaissance Fragility Field Samples Fragility x NDFD24: Corn silage



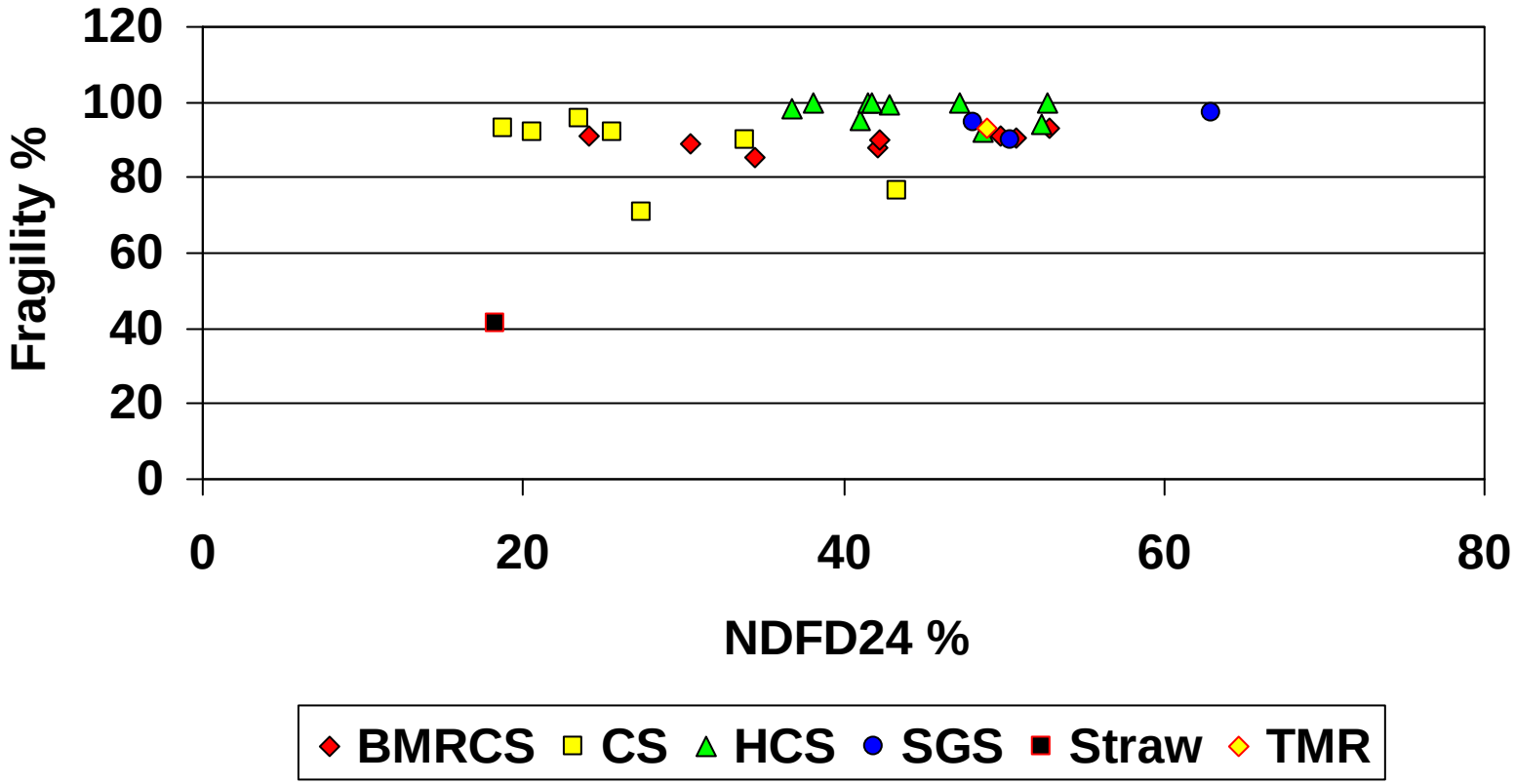
Renaissance Fragility Field Samples NDF, NDFD24 and Fragility: Haylage and SGS

Sample	Type	DM, %	NDF	ADF	ADL	Ash	$NDFD_{24}$	Fragility
HCS 1st cut Leg U. Deleware	HCS	29.0	44.4	35.8	10.2	9.6	38.1	99.9
HCS 1st cut Bunk Brooks	HCS	37.7	54.2	39.2	8.0	7.9	41.0	95.0
HCS Bunk 3 1st cut	HCS	34.8	58.7	36.8	5.2	7.4	52.3	94.0
Alfalfa Haylage 1st cut '08 Ray Bovic	HCS	46.7	33.8	28.4	6.1	9.0	52.7	100.0
Clover Mix Silage Stetanak OH	HCS	45.8	52.0	40.3	8.3	7.2	42.9	99.3
Alf Haylage Dave Gruenbaum	HCS	32.7	51.4	41.7	9.2	7.5	36.8	98.4
Alfafla Haylage Dean Sharp	HCS	46.6	34.2	29.6	7.3	8.2	41.5	100.0
Haylage '08 20x70 Harvestor	HCS	54.3	48.5	38.4	8.6	7.7	47.2	99.6
Haylage 20x70 Concrete silo Bruce Wolf	HCS	35.9	45.1	38.9	9.3	8.6	41.8	99.6
GS Agbag C8 2nd cut 7/15/08	HCS	44.7	54.8	38.1	6.2	9.2	48.7	92.0
SGS Bunk 4 Sean Jones	SGS	28.3	57.0	35.2	4.5	9.2	50.4	90.0
Triticale Silage Bender Dairy	SGS	37.1	59.0	36.1	5.2	8.0	48.1	94.4
SGS Barley Sean Jnes	SGS	27.6	57.1	36.3	5.3	10.5	62.9	97.1
Straw Wheat HB 3"	Straw	87.8	81.6	58.3	13.6	5.3	18.3	41.2
TMR U. Delaware	TMR	55.1	31.3	18.0	3.4	8.1	49.0	93.0

Renaissance Fragility Field Samples Fragility x NDFD24: Haylage and SGS



Renaissance Fragility Field Samples
Fragility x NDFD24: All forages



ADM 2009 Hay vs Straw Cow Trial

- FAQ
  - Can we use “heifer” hay instead of straw for supplemental fiber?
  - Will poor quality hay do the same job as straw to increase peNDF and chewing?
  - Ans:??? “in theory….”
    - Only 1 way to find out

Materials and Methods: Study Design

- Split pen: 36 cows/pen; 20 observed/pen
  - 40 cows observed
  - Pen DMI: estimates
- 3 diets: 1 week periods
  - Baseline Herd ration: 1 lb straw
  - Hay Diet: Baseline ration + 3.6lb Hay
  - Straw Diet: Baseline ration + 3.0lb straw
  - Pen 1: Baseline – Straw – Hay
  - Pen 11: Baseline – Hay - Straw
- 24 h Behavior Watch
  - Eating, Ruminating, Grooming, Drinking, Nothing
  - Stall, Alley
  - Standing, Lying, Perching
- Time Budget
  - 10 min observation intervals

Materials and Methods: Diets and Feeding

Ingredients	Baseline Diet	Hay Diet	Straw Diet
Haylage	10.5	8.3	8.3
Corn Silage	10.5	10.5	10.5
BMR Corn	9.0	9.0	9.0
1st Cut Hay	0.0	3.6	0.0
Straw	1.0	0.0	3.0
Molasses	3.1	3.1	3.1
Cottonseed	1.4	1.4	1.4
Grain Mix	22.4	23.3	23.3

TMR Diets Fed for the Baseline and Two Treatments: lbs fed DM Basis

Results: Nutrient Analysis of forages and TMRs

	NDF	ADF	NDFD24 % NDF	Indig NDF120, % NDF
Ingredients				
Corn Silage	38.2	23.5	39.7	52.7
BMR Corn	39.1	23.0	50.1	28.7
Haylage	44.0	26.7	62.5	28.1
1st Cut Hay	73.7	42.1	32.7	52.1
Straw	83.0	57.1	22.6	66.9
Diet				
Baseline	33.4	18.4	50.9	33.6
Hay	34.3	19.6	51.3	36.2
Straw	33.8	19.6	48.8	37.8

Chemical Analysis of Ingredients and Diets Fed: DM basis

Results: pef and Fragility

	pef (Z-Box)	peNDF (Rotap)	Fragility
Ingredients			
Corn Silage	0.915	34.5	88.5
BMR Corn	0.915	36.2	85.8
Haylage	0.801	29.0	98.3
1st Cut Hay	0.525	33.4	83.2
Straw	0.534	61.6	34.1
Diet			
Base	0.662	21.1	92.0
Hay	0.658	19.7	92.9
Straw	0.665	21.3	91.9

Particle Distribution of Ingredients and Diets Fed: Fiber Relationships

Results:
DMI by Pen and week

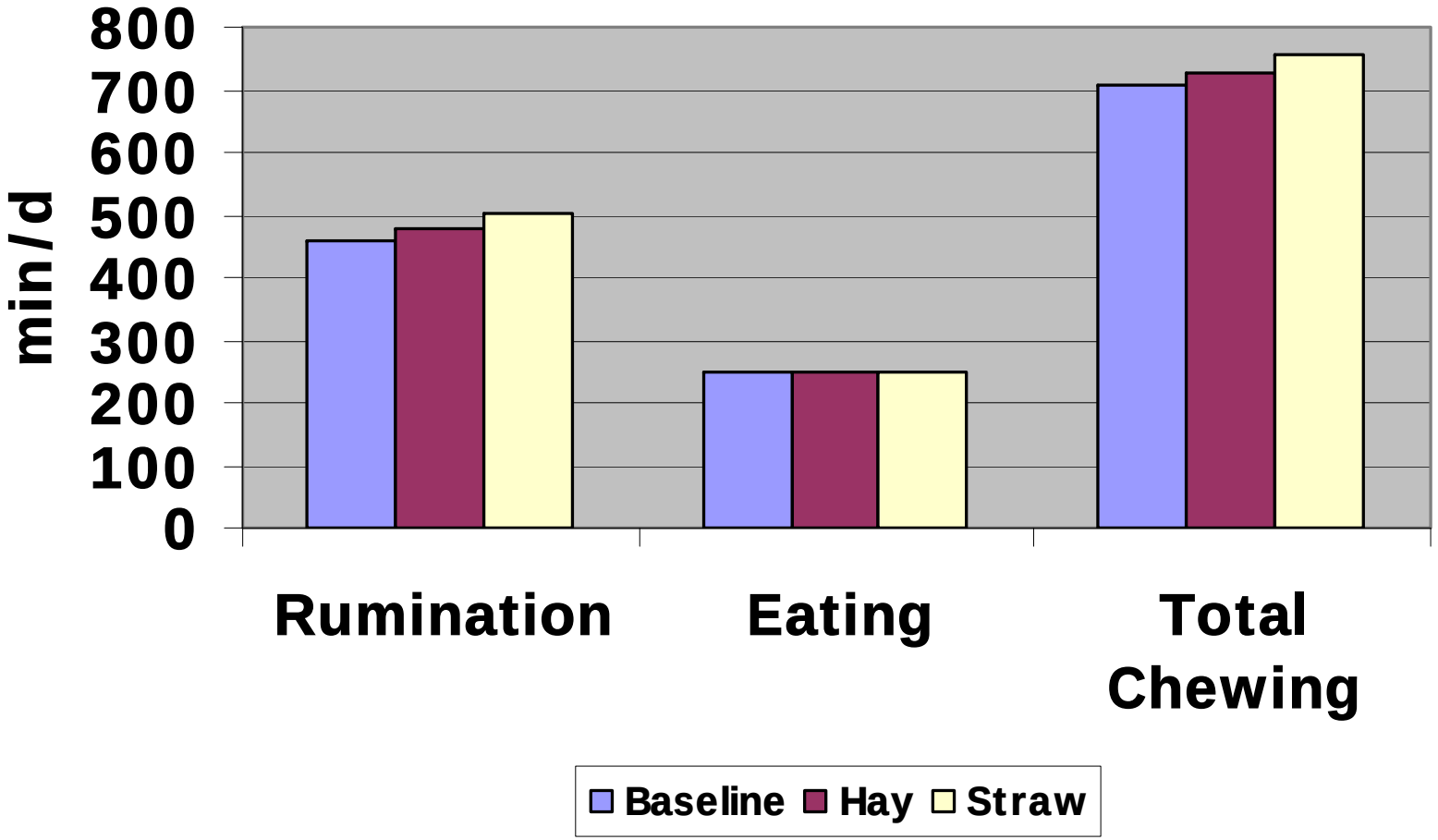
	Pen 1	Pen 11
Hay	63.7	60.7
Straw	64.4	63.1

Estimated DMI: lbs per Pen for each Diet

Results: Chewing Activity and Milk Response, min/d

	Diet			p-values		
	Hay	Straw	SE	Diet	Pen	Week
Behavior Response						
Eating	250.0	249.2	9.2	0.96	0.44	0.001
Ruminating	479.0	504.7	8.5	0.01	0.31	0.18
Total Chewing	728.7	753.9	11.9	0.03	0.96	0.22
Milk Response						
Production lbs	106.3	106.7	3.3	0.76	0.59	0.85
Protein Yield lbs	3.46	3.47	0.1	0.78	0.56	0.26
Fat Yield lbs	3.73	3.77	0.1	0.69	0.02	0.37
FCM lbs	106.5	107.2	3.1	0.69	0.07	0.53

Results: Chewing Activity



Thank you