

INTRODUCTION

- □ Indigestible NDF (iNDF) is defined as plant cell wall carbohydrate which cannot be broken down by the ruminal microbes even after an infinite period (Mertens, 1993)
- □ iNDF describes the innate properties of the cell wall and serves as an ideal nutritional entity because its digestibility is zero (Mertens, 1993)
- □ iNDF has been used as an internal marker when measuring total-tract digestibility (Huhtanen et al., 1994)
- The accuracy and precision of iNDF estimates are dependent on the incubation technique utilized with, bag type and incubation length (Nocek, 1988)
- \Box The recommended methodology is to use 288 h incubation and bags of 6 to 12 µm porosity (Krizsan and Huhtanen, 2013)
- Commercially available ANKOM F57 filter bags (25 μm pores size) and in situ bags (50 μm) were used for the determination of iNDF concentration. However, particle loss due to bag porosity is a potential source of error when incubating heterogeneous particle sizes for a long period (Huhtanen et al., 1994)

OBJECTIVES

 \Box To evaluate effects of bag porosity [nylon bags (15 µm); F57 bag (25 µm) and in situ bag (50 µm)] and sample particle size (1 mm and 2 mm) on the precision of iNDF concentration estimate of feed and feces of dairy cows.

MATERIALS & METHODS

- Two cannulated lactating cows were fed diets containing alfalfa silage, corn, distillers grain, canola meal and soyhulls
- □ Feeds evaluated included:
- Forage:
 - ✓ Alfalfa silage (AS)
 - ✓ Corn silage (CS)
 - ✓ Grass hay (GH)
 - ✓ Wheat straw (WS)
- Byproducts:
 - ✓ Canola meal (CM)
 - ✓ Soybean meal (SBM)
 - ✓ Soy plus (SP)
 - ✓ Soyhulls (SH)
- Four TMRs: 20%, 40%, 60% and 80% concentrate
- Fecal samples (1 mm sample particle size): the same cows fed high-starch diet (FSHS) and fed low-starch diets (FSLS)
- □ Bag dimensions: 5 cm x 5 cm
- □ Samples were incubated 288 h in the rumen
- \Box 3 x 2 factorial arrangements:
 - ✓ There bag pore size: 15 μ m (BS15), 25 μ m (BS25) and 50 μ m (BS50).
- ✓ Two samples particle size: 1 mm (PS1) and 2 mm (PS2)

Email Contacts:

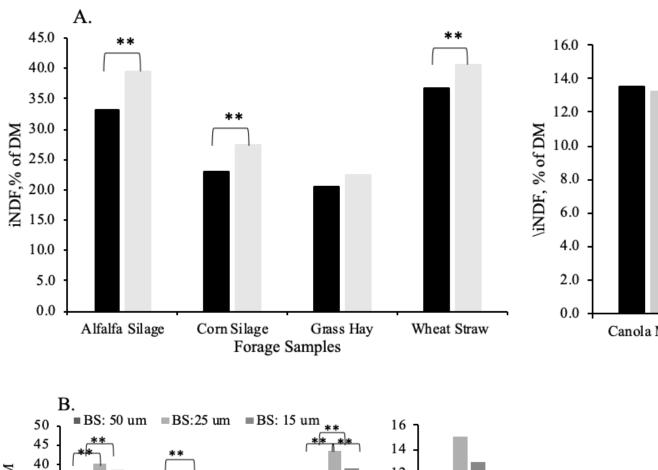
Xiaoxia.dai@usda.gov

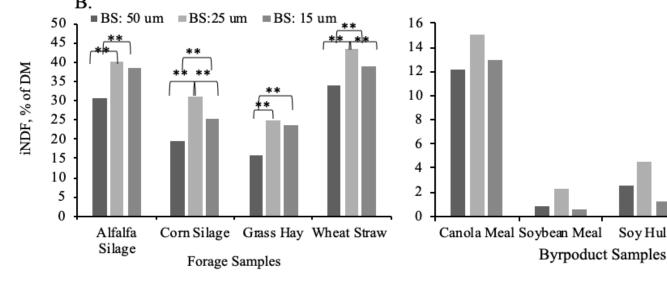
Kenneth.Kalscheur@usda.gov

Effects of bag pore size and sample particle size on feed and fecal indigestible neutral detergent fiber concentration in dairy cows

Table 1 Chen	nical co	mposit	ions of te	ested feed	and fecal	Table 3 Effects	of bag size ar	nd particle size	e on the indig	estible NDF co	oncentration (% of DM) of fe	ed and	
samples						fecal samples	0	•	0		Ň			
Items / %	ems / %		СР	NIDE	iccal samples									
DM	DM		OM	CP	NDF	Items	Bag s	ize = S	Bag si	ze = M	Bag s	ize = L	SEM	
Forage							Particle size $=$ S	Particle size $= L$	Particle size $=$ S	Particle size $= L$	Particle size $=$ S	Particle size $=$ L	SEIVI	
Alfalfa	41.9		89.1	21.2	38.3	Forages						.		
silage						Alfalfa Silage	35.4 ^b	41.7ª	36.9 ^b	42.8ª	27.3°	34.0 ^b	0.83	
Corn silage	30.1		94.5	8.20	42.0	Corn Silage	22.4°	27.8 ^b 24.1ª	29.8 ^b	32.6ª	17.2 ^d 14.1 ^b	22.0° 17.6 ^ь	0.83 0.83	
Grass hay	92.3		92.1	11.0	62.0	Grass Hay Wheat Straw	23.4ª 37.5 ^b	24.1ª 40.4ª	23.9ª 42.1ª	25.7ª 44.0ª	14.1° 30.8°	17.6° 37.1 ^b	0.83	
Wheat straw	85.0		91.7	3.93	78.5	Byproducts	57.5	40.4	42.1	44.0	50.8	57.12	0.85	
Byproducts						Canola Meal	13.2 ^{ab}	12.5 ^b	15.3ª	14.8ª	12.0 ^b	12.4 ^b	0.43	
Canola meal	91.0		92.6	40.9	22.6	Soybean Meal	0.28	0.85	2.33	2.27	0.51	1.17	0.43	
Soybean	90.3		93.2	50.5	7.39	Soy Hull	0.17°	2.30 ^b	4.38ª	4.54ª	2.43 ^b	2.64 ^b	0.43	
meal	00.5		05 5	116	69.2	Soy Plus	1.52	1.29	2.55	2.23	0.48	0.40	0.43	
Soy hulls	90.5		95.5	11.6		TMRs								
Soy Plus	88.6		92.8	46.6	17.6	20% Concentrate	22.4 ^{bc}	27.1ª	24.0 ^b	28.2ª	17.4 ^d	20.6°	0.54	
Fecal samples						40% Concentrate	18.0°	20.8 ^b	18.8°	22.0 ^{ab}	12.6 ^d	15.8°	0.54	
FSLS	92.1		84.8	15.9	49.4	60% Concentrate	13.8 ^b	15.9ª	16.1ª	16.8ª	9.51°	11.8 ^{bc}	0.54	
FSHS	91.6		87.2	17.9	49.2	80% Concentrate	9.45 ^b	8.60 ^b	11.6ª	10.3ª	6.77 ^{bc}	8.16 ^b	0.54	
10110	71.0		07.2	17.5	17.2	Fecal sample	an ash		05.14		17 40		0.52	
Table 2 Dieta	iry ingre	dients	and cher	mical com	positions	High starch	23.0 ^{ab} 26.8 ^a	-	25.1ª	-	17.4° 18.5 ^ь	-	0.53	
of TMRs						Low starch		- h different superscripts	25.8ª	-	18.35	-	0.53	
Items		20%	40%	60%	80%	^{a, b, c, d} Least squares means Bag size: S= 15 μm; M = 2 Particle size: S = 1 mm; L		in uniterent superscripts						
Ingredients (% of die	et DM)	2070	4070	0070	8070	Farticle Size. 3 – T min, L	- 2 11111							
Alfalfa silage	•• 2 1.1)	40.0	30.0	20.0	10.0				Summ	ariae				
Corn silage		40.0	30.0	20.0	10.0				Summ	anes				
Concentrate mix		18.0	38.0	58.0	78.0	BS15PS2 is the	ne recommenc	led methodolog	av to determine	e iNDE concen	tration based (on other studies	2	
Minerals		2.00	2.00	2.00	2.00									
Chemical composition	on					Bag pore size			of all the teste	ed samples, wr	lie sample par	licie size only a		
DM (%)	on	43.5	52.7	61.8	71.0	of forage and	TMR samples							
OM (% DM)		92.7	93.6	94.5	95.4	BS50 with eith	ner PS1 or PS2	2 resulted in the	e lowest iNDF	concentration	for all tested s	amples		
CP (% of DM)		15.1	15.9	16.7	17.5	Concentration	of iNDF for C	S with BS25PS	S1 was not diff	erent from BS1	5PS2			
NDF (% of DM)		35.7	31.8	27.8	23.8	Concentration						t different hetw	een RS25	
ADF (% of DM)		26.8	23.7	20.6	17.6				101 20 /0, 40 /0 0					
Ether Extract (% of]	DM)	3.51	3.59	3.67	3.75	and BS15PS2						-000		
А.						For high NDF	forage, e.g. G	H and WS, BS	25 with either	PS1 or PS2 ca	in replace BS1	5PS2		
45.0		**	16.0		30.0	**	PS: 1 mm							
35.0			14.0		25.0 -		PS: 2 mm			CONCLUS	SIONS			
¥* Q 25.0 - ★**			× 12.0		≥ 20.0 -									
			90 % 8.0 -		б % 15.0 -		\square BS5	0 (in situ bags	s) is not recon	nmended for i	NDF determir	nation		
20.0 - ION 15.0 -			- 0.0 ENDE		LON 10.0 -		$ \square BS2$	5PS2 (F57 ba	as with 2 mm	sample parti	cle size) coulo	d be used to d	etermine	
10.0			4.0 -		5.0 -			N		• •		vith low to med		
5.0			2.0 -		0.0			•	ana shaye, mg	gi ibei ibiage	, and inins v			
Alfalfa Silage Corn Sila For	age Grass Hay rage Samples	Wheat Straw	Cano	bla Meal Soybean Meal	Soy Hull 2 uct Samples	20% Concentrate 40% Concentrate 60% Concentrate 80%	% Concentrate CONC	entrate						
				Бургоц	ict Samples	TMR Samples		al sample (1 n	nm) could be	determined by	/ BS25 (F57 k	bag)		
$\begin{array}{c} B. \\ 50 \\ = BS: 50 \text{ um } = BS: 25 \text{ um } = BS: 15 \text{ um } \\ 16 \\ 1 \\ 16 \\ 16 \\ 16 \\ 16 \\ 16 \\ 1$														
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				25 -		References								
	**	10 -		20 -		** 20 -	- Mortor	D D 1002 Kingd	tion of coll wall digo	ation and passage is	a ruminanta In: H. (
L 25	in III.	8 - 6 -		15 -		** 10			•	•		G. Jung, D. R. Buxton an Society of Agrono		
10		4 - 2 -	الم الم	5 -		5 -					•	digestibility: A review		
0 Alfalfa Corn Silage Grass	ss Hay Wheat Straw	0 Canola Me	al Soybean Meal Soy H	ull Soy Plus	20% 40% 6	0 FS_HS		51–2069.				_ , .	,	
Silage Forage Samples Byrpoduct Samples TMR Samples TMR Samples TMR Samples							 Huhtar 	• Huhtanen, P., K. Kaustell, and S. Jaakkola. 1994. The use of internal markers to predict total digestibility and duodenal						
Figure 1 Effects of particle size (A.) and bag size (B.) on the indigestible NDF								 nutrients in cattle given six different diets. Anim. Feed Sci. Technol. 48:211–227. Krizsan S. J. and Huhtanen P. 2013. Effect of diet composition and incubation time on feed indigestible neutral detergention 						
Figure 1 Effects of particle size (A.) and bay size (D.) of the indigestible NDF (A, B) and facel complete $** D < 0.01$							 Krizsa 	n S. J. and Huhtane	n P. 2013. Effect of	diet composition an	d incubation time or	n teed indigestible ne	eutral deterge	

	_													
Table 1 Cher	nical co	mposi	tions of te	ested feed	and fecal	Table 3 Effects of	of bag size an	d particle size	e on the indige	estible NDF c	oncentration (% of DM) of fe	ed and	
samples						fecal samples	U	•	C					
Items / %	DM		ОМ	СР	NDF									
DM	Divi			Cr	NDF	Items	Bag si	ize = S	Bag siz	ze = M	Bag si	ize = L	SEM	
Forage							Particle size $=$ S	Particle size $= L$	Particle size $=$ S	Particle size $= L$	Particle size $=$ S	Particle size $=$ L	SEIVI	
Alfalfa	41.9		89.1	21.2	38.3	Forages								
silage						Alfalfa Silage	35.4 ^b	41.7ª	36.9 ^b	42.8ª	27.3°	34.0 ^b	0.83	
Corn silage	30.1		94.5	8.20	42.0	Corn Silage	22.4°	27.8 ^b	29.8 ^b	32.6ª	17.2 ^d	22.0°	0.83	
Grass hay	92.3		92.1	11.0	62.0	Grass Hay	23.4ª	24.1ª	23.9ª	25.7ª	14.1 ^b	17.6 ^b	0.83	
Wheat straw	85.0		91.7	3.93	78.5	Wheat Straw	37.5 ^b	40.4ª	42 .1ª	44.0 ^a	30.8°	37.1 ^b	0.83	
Byproducts						Byproducts Canola Meal	13.2 ^{ab}	12.5 ^b	15.3ª	14.8ª	12.0 ^b	12.4 ^b	0.43	
Canola meal	91.0		92.6	40.9	22.6	Soybean Meal	0.28	0.85	2.33	2.27	0.51	12.4°	0.43	
Soybean	90.3		93.2	50.5	7.39	Soy Hull	0.28 0.17°	2.30 ^b	4.38ª	4.54ª	2.43 ^b	2.64 ^b	0.43	
meal						Soy Plus	1.52	1.29	2.55	2.23	0.48	0.40	0.43	
Soy hulls	90.5		95.5	11.6	69.2	TMRs	1.02	1.25	2.00	2.23	0.10	0.10	0.15	
Soy Plus	88.6		92.8	46.6	17.6	20% Concentrate	22.4 ^{bc}	27.1ª	24.0 ^b	28.2ª	17.4 ^d	20.6°	0.54	
Fecal						40% Concentrate	18.0°	20.8 ^b	18.8°	22.0 ^{ab}	12.6 ^d	15.8°	0.54	
samples						60% Concentrate	13.8 ^b	15.9ª	16.1ª	16.8ª	9.51°	11.8 ^{bc}	0.54	
FSLS	92.1		84.8	15.9	49.4	80% Concentrate	9.45 ^b	8.60 ^b	11.6ª	10.3ª	6.77 ^{bc}	8.16 ^b	0.54	
FSHS	91.6		87.2	17.9	49.2	Fecal sample								
Table 2 Dieta	arv inare	dionts	and che	mical com	nositions	High starch	23.0 ^{ab}	-	25.1ª	-	1 7.4 °	-	0.53	
	ary mgrc				positions	Low starch	26.8ª	-	25.8ª	-	18.5 ^b	-	0.53	
of TMRs						a, b, c, d Least squares means v Bag size: S= 15 µm; M = 2	within the same row with $5 \text{ µm} \cdot \text{I} = 50 \text{ µm} \cdot \text{I}$	h different superscripts						
Items		20%	40%	60%	80%	Particle size: S = 1 mm; L =								
Ingredients (% of di	iet DM)													
Alfalfa silage		40.0	30.0	20.0	10.0				Summ	aries				
Corn silage		40.0	30.0	20.0	10.0									
Concentrate mix Minerals		18.0 2.00	38.0 2.00	58.0 2.00	78.0 2.00	BS15PS2 is th	e recommend	ed methodolo	gy to determine	e iNDF concen	tration based of	on other studies	5	
winicials		2.00	2.00	2.00	2.00	Bag pore size								
Chemical compositi	ion											tiole Size only e		
DM (%)		43.5	52.7	61.8	71.0	of forage and								
OM (% DM)		92.7	93.6	94.5	95.4	BS50 with eith	er PS1 or PS2	2 resulted in th	e lowest iNDF	concentration	for all tested s	amples		
CP (% of DM)		15.1	15.9	16.7	17.5	Concentration	of iNDF for C	S with BS25PS	S1 was not diffe	erent from BS ²	5PS2			
NDF (% of DM)		35.7	31.8	27.8	23.8	Concentration						t different hetw	een RS25	
ADF (% of DM)		26.8	23.7	20.6	17.6									
Ether Extract (% of	DM)	3.51	3.59	3.67	3.75	and BS15PS2								
А.						For high NDF	forage, e.g. G	H and WS, BS	25 with either	PS1 or PS2 ca	in replace BS1	5PS2		
^{45.0}		**	16.0		30.0	**								
35.0			14.0 -		25.0 -		■PS: 1 mm PS: 2 mm			ONCLUS	SIONS			
≥ 30.0]		≥ 12.0 ≥ 10.0		≥ 20.0 -		P							
5 25.0 - ×			of 10.0 -		IJ Jo ⊗ 15.0 -		BS5	0 (in situ bag	s) is not recon	nmended for i	NDF determir	nation		
20.0 - ION 15.0 -			HQ 6.0 -		DF.				1				otormino	
10.0 -			4.0 -		<u> </u>			N	•	• •	/	d be used to d		
5.0 -			2.0 -		5.0 -		for co	orn silage, alfa	alfa silage, hig	h fiber forage	e, and TMRs v	vith low to mee	dium	
0.0 Alfalfa Silage Corn Sil	age Grass Hay	Wheat Stray	0.0 v Car	nola Meal Soybean Meal	Soy Hull 0.0	20% Concentrate 40% Concentrate 60% Concentrate 80%	Concentrate CONC	entrate						
Fo	orage Samples			•	ct Samples	TMR Samples			am) aculd ba	datarminad by	, DODE (EET K			
В.								a sample (1 n	nm) could be o		/ DSZS (FS/ L	bag)		
$\begin{bmatrix} 50 \\ 45 \end{bmatrix} = BS: 50 \text{ um} = BS: 25 \text{ um} = BS: 15 \text{ um} \\ ** \\ ** \\ ** \\ ** \\ ** \\ ** \\ ** \\ $				**	References									
		12 -		25 - 20 -		20				Neierei				
30 - · · · · · · · · · · · · · · · · · ·	*	10 - 8 -		15 -		15 -	Merten	is, D. R. 1993. Kine	tics of cell wall diges	stion and passage in	n ruminants. In: H. C	G. Jung, D. R. Buxtor	n, R. D. Hatfie	
20 - 15 -		6 -		10 -	111 III o	10 -	J. Ralp	h, Eds. Pages 535-	570 in Forage Cell \	Nall Structure and [Digestibility. America	an Society of Agrono	my, Madison,	
10 - 5 -		2 -		5 -		5 -	Nocek	, J. E. 1988. In situ a	and other methods t	o estimate ruminal	protein and energy	digestibility: A review	. J. Dairy Sci	
	ss Hay Wheat Straw	0 Canola M	eal Soybean Meal Soy	Hull Soy Plus	20% 40% 60	0 FS_HS	13_13	1–2069.		.	_			
Silage Forage Samp	les		Byrpoduct Samp	bles	Concentrate Concentrate Conce TMR Samples	entrate Concentrate Fecal Samples					•	lict total digestibility a	and duodenal	
Figure 1 Effects of particle size (A.) and bag size (B.) on the indigestible NDF								nutrients in cattle given six different diets. Anim. Feed Sci. Technol. 48:211–227.						
as a sectration $(0/DM)$ of food and food samples $**D < 0.01$							 Krizsar 	 Krizsan S. J. and Huhtanen P. 2013. Effect of diet composition and incubation time on feed indigestible neutral detergent 						





concentration (%DM) of feed and fecal samples. **:P < 0.01.

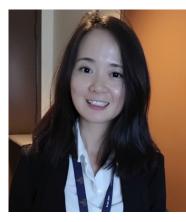
X. Dai and K. Kalscheur

U.S. Dairy Forage Research Center, USDA-ARS, Madison, WI.

RESULTS

concentration in dairy cows. J. Dairy Sci.96:1715–1726





iNDF

25PS2

ne iNDF

tfield, and on, WI.

nal flow of

Effect of diet composition and incubation time on feed indigestible neutral detergent fiber

Funding

This research was funded by USDA-ARS funds.