BENCHMARKING FORAGE NUTRIENT COMPOSITION AND DIGESTIBILITY

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Abstract

Forage quality impacts diet DM intake and energy density, lactation performance, supplemental grain and protein needs, cow health and feed costs. Forage quality is highly variable both among and within forage types. Benchmarks for forage quality and variation in composition for selected nutrients and digestibility parameters are summarized herein from Dairy NRC (2001) tabular data and results from commercial feed testing labs.

Introduction

Forages can comprise over half of the dry matter (DM) in diets for high producing dairy cows depending upon forage quality, inventory and price. Forage quality impacts diet DM intake and energy density, lactation performance, supplemental grain and protein needs, cow health and feed costs. Recent increases in corn and protein supplement prices have been unprecedented, making forage quality of paramount importance for reducing purchased feed costs and improving income over feed cost. The projected impact of forage neutral detergent fiber (NDF) content and in vitro NDF digestibility (IVNDFD; % of NDF) on diet concentrate proportion, amount and cost when meeting minimum diet NDF from forage constraints are provided in Table 1.

Forage quality is highly variable both among and within forage types. Forage species, variety or hybrid, stage of maturity at harvest, cutting, environmental factors, production and harvest practices, storage method (i.e. hay vs. silage, bunker vs. bag, etc.) and ensiling practices all are factors that contribute to this variation. This paper will benchmark forages for quality and variation in composition for selected nutrients and digestibility parameters.

Nutrient Composition

Means and standard deviations for crude protein (CP) and neutral detergent fiber (NDF) and calculated means for total digestible nutrients at a maintenance level of intake (TDN_{1x}) and non-fiber carbohydrate (**NFC**) of selected forages from NRC (2001) table 15-1 are presented in Table 2. CP is highest and NDF is lowest for legume forages. The TDN_{1x} estimate is reasonably similar between legumes and grasses, mainly because the less lignified NDF for grasses compared to legumes results in a higher calculated digestible NDF for grasses, which offsets their lower NFC and CP contents when using the NRC (2001) summative energy equation. However, forage DMI is negatively related to its NDF content in high producing dairy cows (Mertens, 1987), which

may reduce energy intake from grass compared to legume forages. The NDF content of corn silages can be comparable to legume forages, primarily due to dilution with grain that comprises a high proportion of whole-plant corn silage harvested at normal to advanced stages of maturity. Essentially the high NFC content of corn silage results in high TDN_{1x} estimates relative to other forages when using the NRC (2001) summative energy equation. Coefficients of variation (standard deviation divided by the mean times 100) across forages ranged from 12% to 46% and 7% to 16% for CP and NDF contents, respectively.

A survey was conducted of forage analytical data that has been posted on the internet by Cumberland Valley Analytical Services Inc. (CVAS; www.foragelab.com/), Dairyland Laboratories Inc. (Dairyland; www.dairylandlabs.com/), Dairy One Forage Laboratory (Dairy One; www.dairyone.com/Forage/), University of Wisconsin – Madison Soil & Forage Analysis Lab (Marshfield; uwlab.dyndns.org/marshfield/), and Rock River Labs Inc. (Rock River; www.rockriverlab.com). Data (n, average and standard deviation) for selected nutrients and forages are summarized in the tables. DM, CP and NDF contents for legume, grass and mixed hay-crop silages and corn silages are provided in Tables 3, 4, 5 and 6, respectively. The starch content of the corn silages is summarized in Table 7. Averaged across labs and years, the starch content of corn silage was 30.6 ± 6.7. Averaged across labs and years, the starch content of corn silage was 30.6 ± 6.7%.

Digestibility

Fiber

DMI and milk yield are positively related to IVNDFD (Oba and Allen, 1999). IVNDFD data (n, average and standard deviation) for legume, grass and mixed hay-crop silages are provided in Tables 8 (48-h) and 9 (30-h). Both 48-h and 30-h IVNDFD data for corn silage appear in Table 10. Averaged across labs and years, the IVNDFD of corn silage was 58 ± 6% and 51 ± 7% for 48-h and 30-h incubations, respectively.

Starch

Total tract digestibility of starch by dairy cows is variable ranging from 70% to 100% (Firkins et al., 2001). Schwab et al. (2003) developed regression equations to predict corn silage starch digestibility (StarchD) through the total digestive tract in dairy cows. Slopes of the regression equations indicate that DM content had a greater impact on total-tract StarchD of unprocessed than processed corn silage. At 35% whole-plant DM, predicted total-tract StarchD was 5%-units greater for processed than unprocessed corn silage. At lower DM concentrations the difference between processed and unprocessed silage was smaller and increased as DM concentration increased. This may be due to the starch in dryer kernels being less available for digestion. The effect of whole-plant DM content and its interaction with processing will likely vary depending on hybrid type, soil type, growing conditions, and dry-down rate. The processing effect will vary depending on chop length and roll clearance. Therefore, several laboratory methods have been developed to assess StarchD of diverse corn silage samples (i.e. highly variable DM content, chop length, roll clearance, kernel hardness, etc.). Results from various assays to assess StarchD performed at commercial feed testing labs are summarized in Table 11.

Conclusions

Forage quality is highly variable among and within forage types for nutrient composition as well as digestibility. Forage testing is critical to the success of dairy cattle feeding programs, because of the high variability in quality encountered on commercial dairies. An extensive database now exists for in vitro NDF digestibility of hay-crop and corn silages. More translational research on assays to assess the starch digestibility of corn silage is needed before they can be used with confidence in the field.

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Table 1. Impact forage NDF content and digestibility on diet concentrate proportion, amount and cost when meeting minimum diet NDF from forage constraints.

		Forage NDF, % of DM		
Forage IVNDFD	Diet %NDF from Forage	40%	45%	50%
		Concentrate, % of DM		
High ↓ Low	24%	40	47	52
	21%	48	53	58
	18%	55	60	64
		lb. Concentrate DM[1]		
High ↓ Low	24%	20.0	23.5	26.0
	21%	24.0	26.5	29.0
	18%	27.5	30.0	32.0
		Concentrate Cost ($/cow/day)[2]		
High ↓ Low	24%	$3.00	$3.53	$3.90
	21%	$3.60	$3.98	$4.35
	18%	$4.13	$4.50	$4.80

[1] Calculated assuming DMI of 50 lb. per cow per day.
[2] Calculated assuming concentrate price of $0.15 per lb. of DM.

Table 2. Selected nutrient composition of selected forages adapted from NRC (2001) Table 15-1.

Forage	CP% (SD) {n}	NDF% (SD) {n}	TDN_{1x} %	NFC%
	---------- DM basis----------			
Legumes,				
all hay	20.2 (2.6) {12218}	39.6 (6.3) (12178}	58.9	30.5
all silage	20.0 (3.0) {8576}	45.7 (6.5) {8567}	56.6	23.7
Grasses, cool season,				
all hay	10.6 (3.1) {4702}	64.4 (6.2) {4695}	56.3	19.2
all silage	12.8 (3.7) {4401}	60.7 (7.5) {4390}	55.7	18.6
Coastal Bermuda grass hay	10.4 (2.3) {325}	73.3 (5.1) {41}	52.9	9.5
Barley, silage	12.0 (2.6) {528}	56.3 (7.0) {387}	60.2	22.3
Oat,				
hay	9.1 (2.9) {422}	58.0 (6.3) {419}	55.9	23.5
silage	12.9 (1.6) {634}	60.6 (5.7) {632}	56.8	15.4
Wheat,				
silage	12.0 (3.0) {471}	59.9 (7.4) {471}	57.2	17.8
straw	4.8 (1.9) {161}	73.0 (7.1) {107)	47.5	15.1
Corn silage,				
<25% DM	9.7 (2.2) {70}	54.1 (4.6) {70}	65.6	30.3
32-38% DM	8.8 (1.2) {1033}	45.0 (5.3) {1033}	68.8	40.0
>40% DM	8.5 (3.9) {705}	44.5 (5.9) {705}	65.4	41.1
Grain sorghum silage	9.1 (2.6) {1168}	60.7 (8.2) {864}	56.7	22.2
Sorghum sudan,				
hay	9.4 (2.2) {726}	64.8 (5.2) {717}	54.4	17.6
silage	10.8 (3.2) {140}	63.3 (7.2) {139}	54.4	13.8

Table 3. Analysis of legume silages obtained from testing lab summaries.

		DM %			CP, % of DM			NDF, % of DM		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.	n	Avg.	Stdev.
Dairyland	2002	1442	41.7	10.2	1424	20.1	2.4	1425	41.8	4.9
	2003	1261	43.3	10.8	1256	20.3	2.7	1254	40.8	4.9
	2004	1512	42.7	10.8	1499	20.8	2.7	1498	42.7	4.8
	2005	1553	43.9	10.8	1527	20.3	2.6	1526	41.3	4.7
	2006	945	44.2	8.7	940	20.2	1.9	942	40.7	3.5
	2007	1227	44.3	9.8	1211	20.4	2.3	1211	39.8	4.2
Dairy One	2002	4758	42.2	15.3	4613	20.7	2.8	4569	44.9	5.8
	2003	4945	39.6	12.4	4915	21.0	3.0	4828	44.3	5.9
	2004	4147	38.8	11.1	4125	21.0	2.9	4101	44.9	5.9
	2005	3539	39.0	10.8	3513	21.1	2.9	3493	45.2	5.7
	2006	3667	41.0	13.2	3634	21.9	2.9	3643	43.8	5.4
	2007	3625	40.4	12.0	3599	21.5	2.8	3597	44.4	5.4
Rock River	2003	2102	42.9	8.0	2100	20.8	2.1	2094	39.8	4.6
	2004	1979	44.1	8.4	1979	20.4	2.2	1978	41.9	4.9
	2005	1906	43.1	8.0	1905	20.6	2.0	1905	39.0	4.3
	2006	1713	43.4	8.0	1713	20.5	1.9	1709	39.7	4.5
	2007	1410	43.6	8.1	1407	20.3	2.0	1407	40.5	4.3

Table 4. Analysis of grass silages obtained from testing lab summaries.

		DM %			CP, % of DM			NDF, % of DM		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.	n	Avg.	Stdev.
Dairyland	2002	309	39.9	12.6	303	16.2	3.6	301	50.7	6.3
	2003	259	38.5	12.3	257	14.9	3.7	256	52.4	6.8
	2004	291	38.1	13.1	288	15.5	3.7	284	51.9	7.0
	2005	468	35.9	13.1	456	14.2	3.5	457	54.0	7.2
	2006	336	36.8	10.7	352	13.2	2.9	347	53.8	6.4
	2007	404	39.1	11.9	437	14.2	3.0	430	50.8	5.9
Dairy One	2002	3668	40.2	16.5	3600	14.7	3.8	3591	57.8	7.0
	2003	3665	39.8	16.7	3631	14.6	3.8	3615	58.3	7.0
	2004	3776	38.0	14.5	3760	14.3	3.8	3728	59.3	6.6
	2005	3597	38.7	15.2	3553	14.6	3.8	3525	59.0	6.6
	2006	2908	42.3	19.1	2891	15.3	3.9	2880	57.7	7.3
	2007	3107	43.2	19.6	3089	15.0	4.0	3051	58.1	7.5
Rock River	2003	69	46.3	10.6	69	13.9	2.6	67	53.5	6.3
	2004	78	44.7	8.8	78	13.8	2.3	77	54.6	5.8
	2005	121	45.6	9.8	121	13.8	3.2	118	54.5	8.4
	2006	111	46.0	9.6	111	13.9	2.9	111	51.9	7.0
	2007	122	47.3	10.1	122	14.4	2.9	122	52.6	7.7

Table 5. Analysis of mixed hay-crop silages obtained from testing lab summaries.

		DM %			CP, % of DM			NDF, % of DM		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.	n	Avg.	Stdev.
Dairyland	2002	17037	42.0	10.0	16886	19.8	2.6	16775	43.1	5.6
	2003	16515	43.3	10.3	16348	20.0	3.0	16269	41.5	5.5
	2004	17239	42.8	10.0	17120	20.5	2.9	17046	43.4	5.4
	2005	16106	44.3	10.5	15934	20.1	2.7	15880	41.7	5.2
	2006	13675	44.9	8.6	13586	20.0	2.2	13550	41.7	4.1
	2007	16005	45.5	10.0	15899	20.1	2.5	15886	40.9	4.8
Dairy One	2002	10535	38.8	10.5	10527	18.8	3.0	10501	49.2	6.3
	2003	10083	38.4	10.4	10063	18.7	2.9	10053	49.1	6.1
	2004	9778	37.6	10.2	9756	18.7	2.8	9737	50.0	5.8
	2005	8775	37.9	10.4	8737	18.9	2.9	8707	49.7	5.6
	2006	7873	39.3	10.5	7851	20.2	3.0	7830	47.2	5.9
	2007	7974	39.0	10.5	7949	19.9	2.7	7926	47.9	5.6
Rock River	2003	--	--	--	806	17.4	2.6	801	46.2	6.4
	2004	--	--	--	1131	17.1	2.7	1130	47.8	6.0
	2005	--	--	--	1403	17.4	2.8	1397	45.1	6.2
	2006	--	--	--	1941	17.9	2.6	1936	44.4	5.3
	2007	--	--	--	1922	18.2	2.7	1921	44.3	5.5
Marshfield	2002	--	--	--	101	18.3	4.0	101	45.2	7.1
	2003	--	--	--	859	18.9	3.9	859	44.1	8.4
	2004	--	--	--	460	19.1	4.0	460	44.5	7.9
	2005	--	--	--	505	20.0	3.3	505	42.1	6.5
	2006	--	--	--	469	19.7	3.4	469	43.4	7.2
	2007	--	--	--	438	18.3	3.7	438	41.3	6.7

Table 6. Analysis of corn silages obtained from testing lab summaries.

		DM %			CP, % of DM			NDF, % of DM		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.	n	Avg.	Stdev.
Dairyland	2002	13002	37.5	8.4	12444	8.8	1.2	12415	42.1	5.9
	2003	14087	37.7	8.9	13170	8.6	1.1	13112	43.8	5.8
	2004	13325	37.3	8.3	13022	8.4	1.1	13024	44.0	5.9
	2005	14520	36.9	7.3	13860	8.6	1.1	13883	43.6	6.1
	2006	11320	36.9	6.2	11223	8.7	1.0	11290	41.9	5.0
	2007	14961	37.8	7.8	14755	8.5	1.3	14764	43.0	5.8
Dairy One	2002	21606	33.6	11.2	20151	8.4	1.0	21009	44.8	6.0
	2003	20293	33.7	10.0	18950	8.4	1.1	19590	44.2	5.8
	2004	20106	33.8	10.2	18832	8.1	1.0	19650	44.0	6.2
	2005	18402	33.8	11.9	17242	8.0	1.0	17944	44.8	5.7
	2006	18345	34.5	10.8	17375	8.4	0.9	17972	43.8	5.5
	2007	17218	35.0	12.3	16200	8.2	1.0	16912	43.5	6.0
Rock River	2003	606	35.8	5.6	601	7.8	1.0	602	43.1	4.3
	2004	742	35.4	5.6	737	7.4	0.9	738	45.1	4.2
	2005	860	35.6	6.1	860	7.9	0.9	856	46.1	6.1
	2006	844	35.0	5.9	840	8.3	0.9	838	42.5	4.1
	2007	764	35.7	5.1	762	7.6	0.8	762	42.3	4.1
CVAS	--	--	--	--	--	--	--	502	43.3	5.6
Marshfield	2002	--	--	--	157	7.8	1.1	157	39.8	6.2
	2003	--	--	--	676	7.8	1.0	676	42.9	5.8
	2004	--	--	--	466	7.7	1.0	466	43.2	5.2
	2005	--	--	--	459	8.1	1.1	457	41.2	5.9
	2006	--	--	--	866	8.0	1.1	866	39.1	5.9
	2007	--	--	--	451	8.0	--	451	38.6	5.0

Table 7. Starch content of corn silages obtained from testing lab summaries.

		Starch, % of DM		
Lab	Year	n	Avg.	Stdev.
Dairyland	2002	12115	30.0	7.8
	2003	12804	28.5	7.2
	2004	12540	28.7	7.1
	2005	13452	29.6	7.3
	2006	10864	29.7	6.3
	2007	15004	28.5	7.9
Dairy One	2002	13233	29.6	7.5
	2003	13348	30.8	7.5
	2004	14477	31.6	7.6
	2005	14191	30.8	6.8
	2006	16333	31.2	6.8
	2007	15435	31.9	7.2
Rock River	2003	597	34.1	5.9
	2004	735	29.1	5.3
	2005	851	29.6	6.4
	2006	834	32.6	5.7
	2007	761	33.4	5.0
Marshfield	2002	157	34.0	6.2
	2003	676	30.4	6.0
	2004	466	28.5	5.6
	2005	458	30.5	7.0
	2006	865	30.8	7.3
	2007	451	30.7	6.7

Table 8. 48-h IVNDFD for hay-crop silages obtained from testing lab summaries.

		Legume silage			Grass silage			Mixed silage		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.	n	Avg.	Stdev.
		- - - - - - - - - - IVNDFD, % of NDF - - - - - - - - - -								
Dairyland	2002	63	40	8	20	62	6	1089	42	9
	2003	134	51	4	57	55	6	2239	51	4
	2004	199	51	5	64	55	8	4129	51	5
	2005	304	52	5	74	54	8	4208	52	5
	2006	214	52	4	72	50	7	3823	52	5
	2007	274	53	5	105	56	7	4733	53	5
Dairy One	2002	--	--	--	--	--	--	--	--	--
	2003	464	51	6	269	60	7	826	53	6
	2004	261	50	6	58	64	6	123	55	6
	2005	261	52	5	112	66	7	380	54	6
	2006	646	52	5	179	57	6	922	55	6
	2007	474	53	5	125	64	7	668	55	5
Rock River	2003	511	46	6	6	64	9	149	53	6
	2004	626	43	6	11	59	7	262	49	8
	2005	759	46	6	23	61	7	397	51	9
	2006	728	55	6	34	71	8	682	58	5
	2007	631	53	6	37	65	8	775	56	8
Marshfield	2002	--	--	--	--	--	--	101	45	11
	2003	--	--	--	--	--	--	859	51	9
	2004	--	--	--	--	--	--	458	51	7
	2005	--	--	--	--	--	--	505	49	6
	2006	--	--	--	--	--	--	469	49	6
	2007	--	--	--	--	--	--	438	50	7

Table 9. 30-h IVNDFD for hay-crop silages obtained from testing lab summaries.

		Legume silage			Grass silage			Mixed silage		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.	n	Avg.	Stdev.
		- - - - - - - - - - IVNDFD, % of NDF - - - - - - - - - -								
Dairyland	2007	--	--	--	--	--	--	919	45	5
Dairy One	2002	61	49	5	83	62	13	61	52	9
	2003	121	47	7	341	62	9	77	50	7
	2004	134	47	8	186	64	10	129	49	6
	2005	169	48	6	185	61	8	206	50	6
	2006	456	48	7	319	57	7	868	51	6
	2007	853	50	5	483	58	7	2170	52	5
CVAS	2004 -2005	675	45	6	655	56	12	491	53	10

Table 10. IVNDFD for corn silages obtained from testing lab summaries.

		48-h IVNDFD			30-h IVNDFD		
Lab	Year	n	Avg.	Stdev.	n	Avg.	Stdev.
		- - - - - - - - - - IVNDFD, % of NDF - - - - - - - - - -					
Dairyland	2002	2593	60	6	--	--	--
	2003	3842	61	5	--	--	--
	2004	4793	61	5	--	--	--
	2005	5645	60	5	--	--	--
	2006	4624	61	4	--	--	--
	2007	5389	60	4	1865	51	5
Dairy One	2002	--	--	--	1166	55	9
	2003	2369	60	4	873	51	8
	2004	826	59	4	1777	49	8
	2005	1326	58	7	1351	49	6
	2006	2095	59	4	2901	49	5
	2007	1301	62	5	3856	51	6
Rock River	2003	201	51	6	--	--	--
	2004	332	55	6	--	--	--
	2005	417	55	6	--	--	--
	2006	456	62	4	--	--	--
	2007	452	59	4	763	51	6
Marshfield	2002	157	59	9	--	--	--
	2003	676	59	7	--	--	--
	2004	466	59	8	--	--	--
	2005	457	57	10	--	--	--
	2006	865	59	9	--	--	--
	2007	452	54	10	--	--	--
CVAS	2004 - 2005	--	--	--	8231	58	6

Table 11. Results from lab assays to assess starch digestibility (StarchD) for corn silage samples.

		Assay to assess StarchD		
Assay/Lab	Year	n	Avg.	Stdev.
			% of Starch	
DSA/Marshfield	2006	227	92.9	4.7
	2007	31	95.2	3.4
DSA/Tassoul et al., 2007/Dairyland	2006	29	93.7	2.3
Degradability/CVAS	--	502	94.6	3.0
7-h Ruminal in vitro/CVAS	2006 - 2007	5290	62.0	9.7
12-h Ruminal in vitro	2006	29	89.7	5.4
Ruminal + 8-h Post-Ruminal in vitro		29	98.0	1.1
Tassoul et al., 2007/Dairyland-Sapienza				
Kernel Processing Score (<4.75 mm sieve)				
Tassoul et al., 2007/Dairyland	2006	29	54.4	12.7
		55	52.5	14.1
		252	57.7	10.1
CVAS	--	105	44.3	12.3