Using High Quality Forages to Optimize Production

R. D. Shaver

Department of Dairy Science, 266 Animal Sciences Building, 1675 Observatory Drive, University of Wisconsin, Madison, WI 53706
Email: rdshaver@wisc.edu

■ Take Home Messages

- High quality forages increase lactation performance and allow for reduced concentrate feeding which can reduce feed costs.
- Forage quality is highly variable among and within forage types for nutrient composition as well as fiber digestibility.
- Improving forage quality and reducing the variation in forage quality continues to be a major strategy for improving dairy farm profitability.

■ 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 cost. 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.

Table 1. Impact of 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	24%	40	47	52
↓	21%	48	53	58
Low	18%	55	60	64
		kg Concentrate DM[1]		
High	24%	9.1	10.7	11.8
↓	21%	10.9	12.1	13.2
Low	18%	12.5	13.6	14.5
		Concentrate Cost ($/cow/day)[2]		
High	24%	$3.00	$3.53	$3.90
↓	21%	$3.60	$3.98	$4.35
Low	18%	$4.13	$4.50	$4.80

[1] Calculated assuming DMI of 22.7per cow per day.
[2] Calculated assuming concentrate price of $0.33 per kg of DM.

Forage nutrient composition and fiber digestibility are 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.

■ Nutrient Composition

Means and standard deviations for crude protein (CP) and 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. Crude protein 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.

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

▪ Fiber Digestibility

Dry matter intake and milk yield are positively related to IVNDFD (Oba and Allen, 1999). 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). In vitro NDFD data (n, average and standard deviation) for legume, grass and mixed hay-crop silages are provided in Tables 3 (48-h) and 4 (30-h). Both 48-h and 30-h IVNDFD data for corn silage are presented in Table 5.

Table 3. 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
	2008	214	54	5	56	53	9	4109	53	6
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
	2008	255	53	6	118	61	7	441	55	6
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
	2008	--	--	--	--	--	--	56	50	9

Table 4. 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
	2008	--	--	--	--	--	--	1741	46	6
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
	2008	871	51	5	1194	61	7	2125	52	6
CVAS	2004-2005	675	45	6	655	56	12	491	53	10

Brown midrib (bm_3) corn silages are characterized by their lower lignin content and higher fiber digestibility than conventional corn silages (Oba and Allen, 1999b). Eleven bm_3 vs. conventional corn silage comparisons in feeding trials with lactating dairy cows published in the Journal of Dairy Science since 1999 were reviewed. Trials were generally switchback type designs with short-term feeding periods. Forage comprised 55% of diet DM on average across the trials ranging from 44% to 63%. Corn silage comprised 81% of forage DM on average across the trials ranging from 62% to 100%. The MIXED procedure of SAS was used to evaluate the effect of bm_3 corn silage in diets fed to dairy cows on DMI and milk yield, composition and component yields using data from 17 treatment comparisons within the 11 trials. The model included the fixed effect of corn silage treatment and the random effect of trial (St. Pierre, 2001). Dry matter and NDF concentrations were similar for control and bm3 corn silages across the trials. While the starch content of control and bm3 corn silages was similar on average across the trials, the IVNDFD content (% of NDF) of the bm3 corn silages was 11.5%-units greater on average than observed for the control corn silages.

Table 5. 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
	2008	8663	61	4	6760	55	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
	2008	1334	61	6	5396	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	--	--	--
	2008	55	62	7	--	--	--
CVAS	2004 - 2005	--	--	--	8231	58	6

Least square means for DMI and milk yield, composition and component yields for cows fed control and bm3 corn silages in the 11 trials are presented in Table 6. Dry matter intake was 1.2 kg/d greater ($P < 0.01$) for cows fed bm_3 corn silage. Oba and Allen (2000) suggested that reducing physical fill in the rumen by feeding more highly digestible NDF allows for increased DMI in high producing dairy cows. Milk yield was 1.7 kg/d greater ($P < 0.0001$) for cows fed bm_3 corn silage. Tine et al. (2001) and Oba and Allen (1999a) reported that at production levels of intake, increased IVNDFD has minimal impact on diet net energy of lactation (NE_{L-3x}) content but increases NE_L intake primarily through increased DMI. Therefore, the increased milk yield by cows fed bm_3 corn silages can be explained on the basis of increased DMI related to their greater IVNDFD. Milk fat % tended to be reduced ($P < 0.10$) by 0.08%-units for cows fed bm_3 corn silages. Oba and Allen (2000) reported a trend for an interaction ($P < 0.06$) between diet NDF concentration and corn silage hybrid for milk fat %; milk fat % was reduced when bm_3 silage was included in diets with 28% NDF but was not affected when diets contained 38% NDF. Also, Qiu et al. (2003) reported an interaction ($P < 0.05$) between bm_3 corn silage and content of forage NDF in the diet for milk fat %; increasing concentration of forage NDF in the diet with bm_3 corn silage increased milk fat %. Yield of fat (1.40 vs. 1.36 kg/d) was greater ($P < 0.05$) for cows fed bm_3 corn silages and related to the greater milk yield for these cows. Milk protein % was unaffected by treatment. Milk protein yield (1.20 vs. 1.15 kg/d) was greater ($P < 0.001$) for cows fed bm_3 corn silages and related to the greater milk yield for these cows.

Table 6. Effect of brown midrib (bm_3) corn silage in diets fed to dairy cows on dry matter intake (DMI) and milk yield, composition and component yields[1].

	Control	Bm_3	SE	(P <)
DMI, kg/d	24.2	25.4	0.7	0.001
Milk, kg/d	37.7	39.4	1.5	0.0001
Fat, %	3.67	3.59	0.1	0.10
kg/d	1.36	1.40	0.04	0.02
Protein, %	3.08	3.07	0.05	NS
kg/d	1.15	1.20	0.04	0.001

Feeding brown midrib sorghum silage with higher IVNDFD or in situ NDFD (ISNDFD) than a conventional sorghum hybrid increased DMI and fat-corrected milk (FCM) yield in four trials from three reports (Aydin et al., 1999; Grant et al., 1995; Oliver et al., 2004). Similar DMI and FCM yield was observed for BMR sorghum silage versus conventional corn or alfalfa silages in some cases.

Dry matter intake and milk or FCM yield were increased for high vs. low IVNDFD alfalfa silages of similar NDF content (Dado and Allen, 1996), and for early vegetative (low NDF, high ISNDFD) vs. full bloom (high NDF, low ISNDFD) alfalfa hays even though concentrates comprised only 38% of the early-cut versus 55% of the late-cut hay diets (Llamas-Lamas and Combs, 1990). Mertens et al. (2005) and Raeth-Kinght et al. (2005) fed alfalfa hays (30 or 15% of diet DM in each report, respectively) that contained either low NDF (36 to 37% of DM) of varying IVNDFD (38 to 41% of NDF) or high NDF (41 to 42% of DM) of varying IVNDFD (41 to 45% of NDF). Milk yield was not increased by the higher IVNDFD alfalfa hays, but this lack of response to

IVNDFD could likely have been expected considering the small IVNDFD differences between the hays and the low NDF content of the hays.

Milk yield was increased for early cut (high ISNDFD) vs. late-cut (low ISNDFD) wheat silages of similar NDF content (Arieli and Adin, 1994). Ammoniating wheat straw increased IVNDFD and FCM yield at two concentrations of dietary NDF (8.5 or 16% wheat straw diets; Kendall and Combs, 2004). Increased IVNDFD of barley silage increased body weight gain of late lactation cows, but not DMI or milk yield (Chow et al., 2006).

▪ Conclusions

High quality forages increase lactation performance and allow for reduced concentrate feeding which can reduce feed costs. Forage quality is highly variable among and within forage types for nutrient composition as well as fiber digestibility. Forage testing is critical to the success of dairy cattle feeding programs, because of the high variability in quality encountered. Improving forage quality and reducing the variation in forage quality continues to be a major strategy for improving dairy farm profitability. An extensive database now exists for in vitro NDF digestibility of hay-crop and corn silages.

▪ References

Arieli, A., and G. Adin. 1994. Effect of wheat silage maturity on digestion and milk yield in dairy cows. J. Dairy Sci. 77: 237-243.

Aydin, G., R. J. Grant, and J. O'Rear. 1999. Brown midrib sorghum in diets for lactating dairy cows. J. Dairy Sci. 82: 2127-2135.

Chow, L. O., V. S. Baron, R. Corbett, and M. Oba. 2007. Effect of planting date on fiber digestibility of whole-crop barley silage and productivity of lactating dairy cows. J. Dairy Sci. 91:1534–1543.

Dado, R. G., and M. S. Allen. 1996. Enhanced intake and production of cows offered ensiled alfalfa with higher neutral detergent fiber digestibility. J. Dairy Sci. 79: 418-428.

Grant, R. J., S. G. Haddad, K. J. Moore, and J. F. Pedersen. 1995. Brown midrib sorghum silage for midlactation dairy cows. J. Dairy Sci. 78: 1970-1980.

Kendall, C., and D. K. Combs. 2004. Intake and milk production of cows fed diets that differed in dietary NDF and NDF digestibility. J. Dairy Sci. 87(Suppl.1):340(Abstr.).

Llamas-Lamas, G., and D. K. Combs. 1990. Effect of alfalfa maturity on fiber utilization by high producing dairy cows. J. Dairy Sci. 73: 1069-1080.

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64:1548-1558.

Mertens, D. R., H. G. Jung, M. L. Raeth-Knight, and J. G. Linn. 2005. Impact of alfalfa hay neutral detergent fiber concentration and digestibility on Holstein dairy cow performance: I. Hay analyses and lactation performance – USDFRC. J. Dairy Sci. 88(Suppl.1):250(Abstr.).

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Oba, M. and M. S. Allen. 2000. Effects of brown midrib 3 mutation in corn silage on productivity of dairy cows fed two concentrations of dietary neutral detergent fiber: 1. Feeding behavior and nutrient utilization. J. Dairy Sci. 83:1333-1341.

Oba, M. and M. S. Allen. 1999a. Effects of brown midrib 3 mutation in corn silage on dry matter intake and productivity of high yielding dairy cows. J. Dairy Sci. 82:135-142.

Oba, M. and M. S. Allen. 1999b. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Oliver, A. L., R. J. Grant, J. F. Pedersen, and J. O'Rear. 2004. Comparison of brown midrib-6 and -18 forage sorghum with conventional sorghum and corn silage in diets of lactating dairy cows. J. Dairy Sci. 87: 637-644.

Qiu, X., M. L. Eastridge, and Z. Wang. 2003. Effects of corn silage hybrid and dietary concentration of forage NDF on digestibility and performance by dairy cows. J. Dairy Sci. 86:3667–3674.

Raeth-Knight, M. L., J. G. Linn, H. G. Jung, D. R., Mertens, and P. R. Peterson. 2005. Impact of alfalfa hay neutral detergent fiber concentration and digestibility on Holstein dairy cow performance: II. Lactation performance – St. Paul. J. Dairy Sci. 88(Suppl.1):250(Abstr.).

St-Pierre, N. R. 2001. *Invited Review*: Integrating Quantitative Findings from Multiple Studies Using Mixed Model Methodology. J. Dairy Sci. 84:741–755.

Tine, M. A., K. R. McLeod, R. A. Erdman, and R. L. Baldwin. 2001. Effects of brown midrib corn silage on the energy balance of dairy cattle. J. Dairy Sci. 84:885–895.