

# Strategies to Implement High Forage Diets for High Milk Production

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## Take Home Message

- Economic, nutritional, and environmental factors are increasingly encouraging producers to feed higher forage diets.
- Higher forage diets with high forage quality can be fed successfully to dairy cows producing large volumes of milk. In general, high performance cows housed in comfortable facilities and well managed will benefit from high forage diets.
- Use of corn silage to increase the forage content of diets is a popular strategy.
- There is an opportunity to improve nutritional models in their ability to predict forage-neutral detergent fiber digestibility, particle size reduction, passage rate, and cow response.

## Introduction

There is renewed interest in feeding higher forage diets (>60% of ration dry matter) to lactating dairy cows. In an era of high-priced corn and other feed commodities, producers are seeking ways to lower feed costs. One option is to formulate and feed lower starch diets. A lower starch diet can be achieved by either replacing starch with fermentable carbohydrates from non-forage fiber sources (NFFS) or by feeding a higher forage-to-concentrate ration. It is becoming increasingly common for producers to feed at least 60% and potentially more than 70% of the ration dry matter in the form of high quality forages. In general this is accomplished by feeding primarily corn silage. Producers have improved their ability to select, harvest, and store larger quantities of consistent high-quality forages. The use of neutral detergent fiber (NDF) digestibility has helped nutritionists more effectively formulate diets with high forage.

A fundamental question when feeding a higher forage diet to high producing dairy cows is whether productivity can be maintained in comparison to a diet with the traditional 50:50 forage-to-concentrate ratio. Field experiences and controlled research studies indicate that it is possible to maintain productivity as long as there are appropriate cropping and feeding management practices in place that result in large quantities of high-quality forages that are incorporated into rations that are fed appropriately. Cornell researchers have measured herds producing over 36 kg of milk fed rations containing 65 to 70 percent of the total ration dry matter as forage (Chase, 2011). High forage diets are beneficial for many producers given reduced feed costs, better cow health, and improved nutrient management. However, there are some challenges that need to be addressed with high forage diets, such as the need for increased forage inventory of high-quality forages and the need for frequent monitoring of ingredients, rations, and cows.

## Forage and Neutral Detergent Fiber Intake

A fundamental question that arises when formulating high forage diets is "How much forage or forage-NDF can a dairy cow consume?" In theory, a 100% forage diet can be formulated but

practical experience suggests that the cow will not maximize production, efficiency, or profitability. Maximizing forage use in high-producing lactating cow rations involves two factors: 1) maximizing the proportion of forage that can be in the ration and still allow the cow to optimize production and 2) maximizing the digestion and utilization of forage when it is included in a ration (Mertens, 2009). Lactational performance is a function of nutrient intake and digestibility. It is well known that at very high levels of NDF in the ration, intake and performance are reduced and at very low levels of NDF in the ration, intake is reduced. This indicates that there is an optimum NDF level that maximizes intake (Mertens, 2010). Typically, a lactating cow consumes 1.2% of its body weight (BW) with a minimum of 75% of the total NDF intake coming from forage (i.e. 0.9% of BW; Mertens, 2009, 2010). However, cows can consume much more than this amount of fiber when provided with highly digestible forages. Cows on pasture can consume 1.8% of BW (i.e. 2x the benchmarked amount) as forage NDF. With typical Northeastern U.S. diets of bmr corn silage and haycrop silage, Miner Institute (Grant and Cotanch, 2012) has measured total NDF intake in excess of 1.5% of body weight for cows producing over 45 kg milk per day. The "gut fill" effect is determined by forage-NDF content, forage particle size, fragility of forage-NDF, and NDF digestibility within a forage family (Allen, 2000). These factors will be influenced by forage type (i.e. legumes, perennial grasses, and annual grasses).

### Forage Type, Quality, and Allocation

Targeted use of consistent high-quality forages is key for successful use of high forage diets for high producing cows. Forages have been traditionally analyzed for protein and fiber fractions for use in ration formulation. More recently, analyzing forages for digestibility of fiber (NDF) is gaining popularity because of its value in ration formulation and modeling. Chemical composition and digestibility data of forages analyzed at Dairy One over a 1-year period indicates that forage quality is variable within and among forage types (Table 1). Thus, forages should be analyzed before diets are formulated.

**Table 1. Composition and digestibility for ensiled forages analyzed from May 2012 to April 2013 at Dairy One ([www.dairyone.com](http://www.dairyone.com)).**

Forage	Item	Samples, #	Mean	Standard Deviation
Corn silage	CP, % DM	15,542	8.4	1.2
	Starch, % DM	14,663	32.9	7.8
	NDF, % DM	15,526	42.6	6.2
	24-h NDFD, % NDF	4,366	44.0	6.0
Legume silage	CP, % DM	2,583	22.4	2.8
	NDF, % DM	2,593	42.5	5.3
	24-h NDFD, % NDF	619	43.7	5.8
Mixed mostly legume silage	CP, % DM	4,601	20.7	3.2
	NDF, % DM	4,588	46.4	6.3
	24-h NDFD, % NDF	1,572	45.9	6.4
Mixed mostly grass silage	CP, % DM	7,739	16.1	3.5
	NDF, % DM	7,698	56.2	6.5
	24-h NDFD, % NDF	2,778	51.0	6.4
Grass silage	CP, % DM	3,815	14.9	4.1
	NDF, % DM	3,817	58.6	7.2
	24-h NDFD, % NDF	1,468	50.8	6.8

Assessments of the chemical composition and digestibility of forages allow forages to be targeted to the appropriate group of cows. In general, high producing cows should be fed diets that are less filling and highly fermentable to maximize feed intake whereas low producing cows should be fed diets that are more filling and less fermentable (Allen, 2011). The filling effect is determined primarily by the concentration and digestion characteristics of the forage fiber (Allen, 2000). Classic work (Oba and Allen, 1999) demonstrated that a one-unit increase in NDF digestibility measured in vitro or in situ was associated with a 0.17-kg increase in dry matter intake and a 0.25-kg increase in 4% fat-corrected milk within forage family. Importantly, the intake and milk responses to improved digestibility of NDF are greater for the higher producing cows than the lower producing cows.

At Miner Institute, higher forage diets work best when the bmr corn silage and haycrop silage (mixed, most grass) have a 24-h NDF digestibility >55%. The 24-h NDF digestibility of the diet is typically >60%. In order to achieve these targets there is a heavy emphasis placed on harvesting the crops at the correct stage of maturity, packing the forage sufficiently to ensure a proper fermentation, and segregating forages based on quality to allow targeted feeding. Higher quality forages are reserved for the early and peak lactating cows while poor quality forages are used for late lactation cows, dry cows, and heifers.

It is increasingly common for high producing herds to fed higher forage diets with a majority of the forage coming from conventional or bmr corn silage. The remainder of the forage is often legume or perennial grass. A frequent question is "Are legumes or grasses better for high forage diets?" Both types of forage have been used successfully in high producing herds (Chase, 2011). Recently, Chase (2012) suggested that using primarily grass forages in lactating cow rations is a viable option when soils limits the potential for growing corn silage or alfalfa. Typically, forage quality is more important than forage type. However, there are some differences in forage types that are worth considering as cropping strategies are reviewed.

Perennial grass, such as orchardgrass is more filling than NDF from annual grass, such as corn silage, or a legume such as alfalfa. Although the perennial grass has greater digestibility, it passes slower from the rumen than the alfalfa (Voelker Linton and Allen, 2008). This is likely caused by differences in the rate of particle size reduction and rate of increase in particle specific gravity. The rates are faster for legume forages and grass forages (Voelker Linton and Allen, 2008). In addition, forages containing a high proportion of perennial grass would be better targeted to lower producing cows whose feed intake is less limited by gut fill (Allen, 2011). Use of mixed legume-grass forages should be tested to determine nutrient composition and how to target the forage. Often, inclusion of mostly grass forage is limited in high producing cows.

### **Benefits and Challenges to Feeding Higher Forage Diets**

A number of producers feeding higher forage diets to lactating cows were surveyed (Chase, 2011; Hoard's Dairyman, 2013). The producers listed several benefits to feeding higher forage diets including:

- Minimized purchased grain costs
- Improved income over purchased feed costs
- Improved milk component levels
- Improved manure consistency
- Improved reproductive performance
- Improved health
- Lowered incidence of acidosis and metabolic disorders
- Lowered incidence of lameness
- Lowered veterinary costs
- Lowered culling rates; allowed more voluntary culling

Along with several benefits to feeding higher forage diets, there are some accompanying risks or challenges (Chase, 2011; Hoard's Dairyman, 2013). One of the big ones is mindset (Chase, 2011). Are the producer, nutritionist, and feed mixing person ready and willing to make higher forage diets work? Often a mindset is changed by crisis or by accident. However, it can be very powerful and motivating when changed purposely. The producer is responsible for setting and managing the mindset of his business and employees.

The decision to feed a higher forage diet impacts more than just the feed mixing person. It impacts every component of a dairy farm including crop production and harvest, feed storage and feeding management, herd management, and manure management. Often a more intensive crop management strategy is needed to select, plant, harvest, and ensile improved forage hybrids and varieties to provide the quality that is necessary. There may be additional expenses associated with inoculants, seed cost, fertilizer, storage facilities, and labor to achieve higher quality forages.

Another challenge is forage inventory management. A higher amount of corn silage and/or haycrop silage in the diet requires harvesting or purchasing more as-fed tons to meet the yearly requirement. It takes time to build forage inventory. Without the appropriate crop acres or purchasing ability there may not be enough forage to feed the level of "high forage" desired. Weather can also impact the ability to produce a sufficient quantity of high-quality forages. In general, it is recommended for producers to plan for 15 to 40% more tonnage depending on level of forage fed and to which groups the forage is fed. Producers also need to consider forage storage capacities and the ability to segregate storage space based on quality (i.e. NDF digestibility).

### **Comparison of Higher Forage Diets with Other Feeding Strategies**

Recently, Miner Institute (Dann et al., 2012) conducted a study that evaluated how a higher forage diet based on corn silage compared with a standard diet containing 50% forage and a diet containing NFFS in place of corn meal (Table 2). The higher forage and the NFFS diets both contained similar, and lower, starch content than the standard diet. The standard diet contained 20% conventional corn silage, 20% bmr corn silage, and 10% haycrop silage (mixed, mostly grass) for a total of 50% forage in the ration dry matter. In contrast, the higher forage diet contained 53% bmr corn silage and 10% haycrop silage for a total of 63 % forage in the ration dry matter. Brown midrib corn silage was used as the primary forage in an effort to enhance the digestibility of NDF from forage. The diet based on NFFS contained the same forage sources and amounts as the standard diet (50% total forage), but corn meal was reduced to only 4% of ration dry matter and replaced with beet pulp (11%), wheat middlings (11%), and distillers grains with solubles (4%). All three diets contained similar crude protein (16.6%) and protein fractions, fat (3.9%), and sugar (6.8%). Dietary NDF was lower for the standard diet (34.7%) than either the higher forage or non-forage fiber source diets which were similar (38.2%). The peNDF content of the standard diet was also lower (19%) than the higher forage diet (25%) simply reflecting the differences in forage content, and the NFFS diet was intermediate at 22%. Starch content was greatest for the standard diet (26.0%) and lower for the higher forage diet (21.4%) and NFFS diet (21.3%).

Lactational performance is summarized in Table 3. Dry matter intake was greatest for cows fed the standard diet, intermediate for the NFFS diet, and lowest for the higher forage diet. The lower intake for the higher forage diet likely reflected the higher forage NDF and peNDF content of this diet. The intake of NDF as a percentage of BW was greater for the higher forage diet and the NFFS diet relative to the standard diet. In fact, 1.35% of BW for intake of NDF is a very high

level of NDF consumption, and consequently the high forage-NDF intake may have limited dry matter intake for cows fed the higher forage diet despite the fact that it was comprised primarily of bmr corn silage.

**Table 2. Composition (% dry matter basis) of a standard diet, a higher forage diet, and a diet containing non-forage fiber sources (NFFS) fed to lactating Holstein cows.**

Item	Treatment		
	Standard	Higher Forage	NFFS
<b>Ingredient composition</b>			
Corn silage	20.0	-	20.0
Brown midrib corn silage	20.0	53.3	20.0
Haycrop silage (mixed, mostly grass)	10.0	10.0	10.0
Corn meal	15.0	-	3.8
Soybean meal	8.3	6.7	3.8
Canola meal	6.7	6.7	6.7
AminoPlus	4.3	4.3	4.3
Beet pulp	5.0	5.0	10.8
Wheat middlings	5.0	5.0	10.8
Distillers dried grains with solubles	-	3.3	4.2
Other	5.7	5.7	5.7
<b>Chemical composition</b>			
Crude protein, %	16.6±0.1	16.8±0.1	16.3±0.2
Neutral detergent fiber, %	34.7±0.7	38.3±1.6	38.0±0.7
Acid detergent fiber, %	21.0±0.2	23.1±1.1	23.4±0.6
Starch, %	26.0±0.4	21.4±0.7	21.3±0.6
Sugar, %	7.0±0.1	6.6±0.3	6.9±0.3
Fat, %	3.9±0.1	3.7±0.2	4.1±0.2
<b>Digestibility</b>			
24-h neutral detergent fiber, %	54.1±0.6	53.0±1.1	51.6±1.7
2-h starch, %	26.3±1.1	29.2±2.8	32.6±2.4
7-h starch, %	75.2±1.3	78.1±2.1	79.7±0.4

**Table 3. Lactational response of lactating Holstein cows fed a standard diet, a high forage diet, and a diet containing non-forage fiber sources (NFFS) fed to lactating Holstein cows.**

Item	Treatment			SE	P-value
	Standard	Higher Forage	NFFS		
DMI, kg/d	28.2 <sup>x</sup>	27.2 <sup>y</sup>	27.7 <sup>xy</sup>	0.8	0.08
DMI, % of BW/d	3.85 <sup>a</sup>	3.67 <sup>b</sup>	3.75 <sup>ab</sup>	0.10	0.02
NDF intake, kg/d	9.1 <sup>b</sup>	10.0 <sup>a</sup>	9.9 <sup>a</sup>	0.3	<0.01
NDF intake, % of BW/d	1.23 <sup>b</sup>	1.35 <sup>a</sup>	1.34 <sup>a</sup>	0.03	<0.01
peNDF intake, kg/d	5.2 <sup>c</sup>	6.5 <sup>a</sup>	6.1 <sup>b</sup>	0.2	<0.01
Milk, kg/d	51.6 <sup>ax</sup>	48.4 <sup>by</sup>	50.5 <sup>abx</sup>	2.3	<0.01
SCM, kg/d	49.0	47.3	48.5	1.9	0.40
Fat, %	3.66 <sup>y</sup>	3.98 <sup>x</sup>	3.76 <sup>xy</sup>	0.17	0.07
Fat, kg/d	1.86	1.88	1.86	0.08	0.92
True protein, %	3.10	3.07	3.08	0.06	0.47
True protein, kg/d	1.58 <sup>ax</sup>	1.45 <sup>by</sup>	1.54 <sup>abx</sup>	0.05	0.01
Milk/DMI	1.83	1.77	1.82	0.06	0.20
SCM/DMI	1.73	1.74	1.75	0.04	0.88

<sup>abc</sup> Least squares means within a row without a common superscript differ ( $P \leq 0.05$ ).

<sup>xy</sup> Least squares means within a row without a common superscript differ ( $P \leq 0.10$ ).

Although milk yield was reduced for cows fed the higher forage diet, milk fat percentage was elevated, and so solids-corrected milk yield was similar for all diets as was efficiency of solids-corrected milk production. Total chewing time was greatest for cows fed the higher forage diet (793 min/d; 29 min/kg dry matter), intermediate for the non-forage fiber diet (776 min/d; 28 min/kg dry matter), and least for the standard diet (766 min/d; 27 min/kg dry matter). Ruminal pH was least for cows fed the standard diet (6.09), highest for cows fed the higher forage diet (6.16), and intermediate for the non-forage fiber diet (6.11). Finally, microbial protein production was similar for all three diets (594 g/d). The results of this study showed that higher forage diets can be fed successfully if the forage contains highly digestible NDF (as in the case of bmr corn silage).

There is a need to better understand and model rumen fiber digestion kinetics (e.g. digestion and passage) to optimize forage use in high producing cows (Grant and Cotanch, 2012). Miner Institute (Cotanch et al., 2012) conducted a study to measure the effect of various forage treatments (Table 4) on rumen conditions and forage passage dynamics, chewing responses, and lactational performance. The major differences among the four diets were the forage content (~50% versus ~65%) and the forage NDF source (conventional versus bmr corn silage).

**Table 4. Composition (% dry matter basis) of diets of conventional corn silage (CS) or brown midrib corn silage (BMR) fed to lactating Holstein cows.**

Item	Treatment			
	Low CS	High CS	Low BMR	High BMR
<b>Ingredient composition</b>				
Conventional corn silage	39.3	55.0	-	-
Brown midrib corn silage	-	-	36.1	50.2
Haycrop 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	30.1	30.1
<b>Chemical composition</b>				
Crude protein, %	17.0±0.1	17.0±0.1	16.7±0.3	16.7±0.1
Neutral detergent fiber, %	32.1±0.4	35.6±0.4	31.5±0.3	35.1±0.2
Acid detergent fiber, %	19.4±0.4	23.0±0.6	19.3±0.8	22.0±0.6
Starch, %	28.0±0.9	21.2±0.5	27.8±0.9	23.8±0.7
Sugar, %	4.4±0.2	3.9±0.3	4.3±0.2	4.3±0.4
Fat, %	4.0±0.1	3.9±0.1	4.4±0.2	4.5±0.2
<b>Digestibility</b>				
24-h neutral detergent fiber, %	56.3±1.5	54.0±1.4	62.0±1.8	60.3±1.4

Table 5 summarizes the lactational performance responses to these diets. In general, cows responded to the forage treatments as predicted based on previous research with bmr corn silage and diets of varying forage content. Dry matter intake was lowest for the cows fed the higher level of conventional corn silage (related to lower ruminal turnover of NDF). The intake of NDF as a percentage of BW was high for all diets, but was increased specifically for cows fed the bmr corn silage in a high forage diet. Similar to feed intake, solids-corrected milk production was unaffected by source of corn silage at the lower forage content, but it was significantly increased by bmr corn silage when fed in a higher forage diet. Efficiency of milk production was unaffected by source of corn silage at either level of dietary forage.

Chewing time and ruminal pH were enhanced by the higher amount of dietary forage and reduced by the bmr versus the conventional corn silage (Table 6). Microbial protein production was increased by bmr versus conventional corn silage which presumably reflected the greater fermentability of that forage.

**Table 5. Lactational response of lactating Holstein cows fed diets of conventional corn silage (CS) or brown midrib corn silage (BMR).**

Item	Treatment				SE	P-value
	Low CS	High CS	Low BMR	High BMR		
DMI, kg/d	29.0 <sup>a</sup>	26.5 <sup>b</sup>	29.3 <sup>a</sup>	29.2 <sup>a</sup>	0.7	<0.01
DMI, % of BW/d	4.31 <sup>a</sup>	3.96 <sup>b</sup>	4.37 <sup>a</sup>	4.36 <sup>a</sup>	0.12	<0.01
NDF intake, kg/d	9.36 <sup>b</sup>	9.47 <sup>b</sup>	9.32 <sup>b</sup>	10.25 <sup>a</sup>	0.22	<0.01
NDF intake, % of BW/d	1.39 <sup>b</sup>	1.41 <sup>b</sup>	1.39 <sup>b</sup>	1.53 <sup>a</sup>	0.04	<0.01
Milk, kg/d	47.0 <sup>a</sup>	43.1 <sup>b</sup>	48.6 <sup>a</sup>	47.2 <sup>a</sup>	1.6	<0.01
SCM, kg/d	46.3 <sup>a</sup>	41.7 <sup>b</sup>	47.8 <sup>a</sup>	46.0 <sup>a</sup>	1.1	<0.01
Fat, %	3.82 <sup>ab</sup>	4.02 <sup>a</sup>	3.76 <sup>b</sup>	3.94 <sup>ab</sup>	0.14	0.04
Fat, kg/d	1.83	1.71	1.87	1.85	0.05	0.12
True protein, %	3.06 <sup>ab</sup>	2.92 <sup>c</sup>	3.10 <sup>a</sup>	3.02 <sup>b</sup>	0.05	<0.01
True protein, kg/d	1.48 <sup>ab</sup>	1.25 <sup>c</sup>	1.55 <sup>a</sup>	1.43 <sup>b</sup>	0.04	<0.01
Milk/DMI	1.62	1.62	1.66	1.61	0.04	0.46
SCM/DMI	1.56	1.58	1.58	1.57	0.03	0.74

<sup>abc</sup> Least squares means within a row without a common superscript differ ( $P \leq 0.05$ ).

Table 6 summarizes ruminal turnover for NDF among the four diets. At either level of forage in the diet, bmr corn silage reduced ruminal digesta volume and mass (either statistically or numerically depending on the comparison). The NDF pool was reduced for cows fed the bmr corn silage in lower forage diets, but relatively unaffected by source of corn silage at higher forage diets. Even though the NDF pool size was similar between the conventional and bmr corn silages with the higher forage diet, the NDF dynamics were quite different. With conventional corn silage, intake was reduced, ruminal turnover rate was lower, and time in the rumen was longer. In contrast, for the bmr silage in a higher forage diet, dry matter intake was higher, ruminal turnover rate was greater, and time spent in the rumen was less.

**Table 6. Chewing and ruminal response of lactating Holstein cows fed diets of conventional corn silage (CS) or brown midrib corn silage (BMR).**

Item	Treatment				SE	P-value
	Low CS	High CS	Low BMR	High BMR		
Total chewing, min/d	7896 <sup>a</sup>	844 <sup>a</sup>	713 <sup>b</sup>	809 <sup>a</sup>	24	<0.01
Ruminal pH	6.09 <sup>ab</sup>	6.17 <sup>a</sup>	6.00 <sup>b</sup>	6.07 <sup>ab</sup>	0.08	0.02
Microbial N, g/d	510 <sup>ab</sup>	456 <sup>b</sup>	551 <sup>a</sup>	542 <sup>a</sup>	23	<0.01
Ruminal digesta, L	123 <sup>ab</sup>	128 <sup>a</sup>	113 <sup>b</sup>	119 <sup>ab</sup>	3	0.01
Ruminal digesta, kg	106 <sup>ab</sup>	112 <sup>a</sup>	98 <sup>b</sup>	105 <sup>ab</sup>	3	0.02
NDF pool, kg	8.32 <sup>ab</sup>	8.45 <sup>a</sup>	7.64 <sup>b</sup>	8.36 <sup>ab</sup>	0.41	0.02
NDF turnover, %/h	4.84 <sup>b</sup>	4.76 <sup>b</sup>	5.12 <sup>ab</sup>	5.52 <sup>a</sup>	0.30	<0.01
NDF turnover time, h	21.1 <sup>a</sup>	21.4 <sup>a</sup>	20.3 <sup>ab</sup>	19.0 <sup>b</sup>	1.1	0.01

<sup>ab</sup> Least squares means within a row without a common superscript differ ( $P \leq 0.05$ ).

## Keys to Making Higher Forage Diets Work

Producers that are successful implementing high forage diets for high producing cows plan and execute management practices effectively. There are some key questions that every producer must address before implementing higher forage diets:

- Does the producer have the right mindset to successfully manage higher for diets?
- Does the producer have the ability to produce, harvest, store, and feed high-quality forage?

Producers using high forage diets successfully:

- Account and plan for the additional forage tonnage needed. Adequate acreage is critical.
- Consider and plan for the additional storage space needed for the forage(s)
- Monitor forage inventory at least monthly. This task is easier with feed management software
- Produce high quality forage that focuses on NDF content and digestibility
- Harvest forage at the appropriate moisture content, chop to the recommended particle size, and pack the forage to ensure proper fermentation. Process the kernels in corn silage
- Store forages of different qualities in separate structures to allow appropriate targeting of foraged to groups of cows based on production level and days in milk
- Know their cost of growing or purchasing forages vs. other feed ingredients
- Select highly digestible forages (e.g. bmr corn silage)
- Analyze forage on a regular basis to adjust diets as needed. Starch digestibility in corn silage will increase for several months after ensiling.
- Balance diets to provide adequate nutrient to meet requirements for performance is not limited
- Use corn meal instead of high moisture corn when feeding very high (>60%) amounts of corn silage
- Adjust diets based on economics while maintaining performance and health
- Track dry matter intake. Intake will increase more in high producing cows than low producing cows.
- Use feed management software to track inventories and monitor intake and efficiencies of production
- Use a TMR mixer that is big enough to mix the bulkier loads. A mixer that is too small will not mix well and contribute to sorting, intake variation, and digestive upset.
- Monitor manure consistency and reassess the diet when manure is loose or inconsistent. Think about passage rate.
- Analyze fecal starch content to indicate if proper silage processing occurred. Fecal starch content >5% typically needs ration evaluation and adjustment.
- Monitor sorting, dietary peNDF, and rumination. Don't dilute the diet with large quantities of low quality forage. Use 1 to 2 lbs of straw to provide peNDF and control passage rate
- Have good management practices and facilities in place to support cow comfort and daily time budgets.
- Provide adequate bunk space and access to allow a larger quantity of feed to be consumed. Address number of times fresh TMR is delivered and TMR is pushed up
- Realize that high forage diets are not always the best option. A high forage diet will not "fix" a poorly managed herd.

Use of corn silage to increase the forage content of diets is a popular strategy. There are several guidelines for feeding high corn silage diets to maintain ruminal health and lactational performance (Chase, 2011; Shaver, 2013; Miner unpublished data). The guidelines are a place to start in diet formulation. Cows should be monitored closely and diets adjusted as needed.

Minimum allowances for NDF, forage-NDF, and peNDF are 27-30%, 19-21%, and 20-21%, respectively. If a large proportion of the corn silage is highly digestible (e.g. bmr corn silage) than a higher forage-NDF (i.e. 23-24%) may be more appropriate. Starch content of the diet can range from 18 to 30%. However, ruminal starch content and degradability should be evaluated to avoid too much of a quickly fermentable carbohydrate load. In general, non-forage fiber sources are good substitutes for corn grain in high corn silage diets. Less starch should be included in the diet if the corn silage was immature and wet or if the diet included finely processed high-moisture corn. However, results from a meta-analysis (Ferraretto and Shaver, 2012) indicated that starch digestibility and lactation performance were reduced for cows fed diets containing corn silage with >40% dry matter or corn silage with insufficient kernel processing.

With high corn silage diets, high dietary fat concentration (>5%) should be avoided to minimize negative effects on trans fatty acids and milk fat composition. The use of corn co-products (e.g. corn gluten meal and distillers grains) should be limited to avoid amino acid balancing problems with particular attention given to lysine. Soybean and animal products work well in high corn silage diets. Crude protein content can range from 15-18% with lower crude protein included in the diet with good rumen function and microbial protein yield.

## Conclusions

Feeding higher forage diets is an opportunity on many farms given the current economical and environmental pressures. However, there is no "one-size fits all" approach. It is an individual farm decision that requires the appropriate mindset and integration of many factors, such as crop acres available (inventory), storage facility availability, forage quality, CAFO plans, and feeding equipment and management.

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