In Vivo Digestibility of Forages

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Introduction

There has been a trend for dairy producers to feed higher forage rations over the last 5 to 10 years. A primary reason is that producers are doing a better job of harvesting and storing larger quantities of high quality forages. The use of the neutral detergent fiber **(NDF)** digestibility concept has also provided additional information to assist feed professionals in formulating dairy rations with higher levels of forage. There have also been improvements in the corn hybrids and forage varieties available in terms of NDF digestibility. A key reason for including more forage in the ration in many herds is an attempt to minimize herd health disorders related to feeding high nonfiber carbohydrates and starch levels in dairy rations. In addition, incorporating a greater proportion of higher quality forages in the diet reduces feed costs. In some instances, it may also have the added benefit of increased nitrogen use by the cow and thereby strategically improve nutrient management on the farm.

However, many factors affect the quality and quantity of forages that can be incorporated into lactating cow rations. Variation in forage quality can impact dry matter **(DM)** intake, diet energy density, dietary grain and protein supplementation amounts, feed costs, lactation performance, and cow health. Forage quality is highly variable among and within forage types (NRC, 2001). Forage species, variety or hybrid, stage of maturity at harvest, cutting, environmental factors, production and harvest practices, storage method, and ensiling practices all are factors that contribute to this variation (Shaver et al, 2002). These are many of the forage variables. There are then many factors that affect the fiber requirements of lactating dairy cows and the amount of forage DM that can be incorporated into the ration. These include level of intake, quality and type of the forage source, amount and type of nonstructural and structural carbohydrates in the ration DM, particle size and processing method of forages and grains, rate and extent of fermentability of the fiber source, ruminal fermentation characteristics, and management of feed allocation. The challenge for the nutritionists is to provide guidance in ration formulation that allows for a high incorporation of forages in the ration without compromising milk yield or components.

All factors affecting in vivo forage digestibility certainly cannot be addressed in one paper; therefore, efforts will be placed on understanding the factors that contribute to the use of quality forages in lactating cow rations. The topics that will be covered include: factors affecting forage fiber digestion, such as DM intake, the interaction of concentrates and other fiber sources in the ration with forage sources, and processing and particle size of forages, and influences on performance and milk components.

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Why is Knowing Forage Fiber Digestibility Important?

Oba and Allen (1999) evaluated the relationship between fiber digestibility and animal performance using 45 sets of treatment means from 27 articles published in the Journal of Dairy Science. These 27 articles had reported significant differences in NDF digestibility in vivo, in situ, or in vitro. Experiments with cows averaging less than 100 days in milk **(DIM)** at the midpoint were classified as early lactation and classified mid-lactation otherwise. There was a 5.2% increase in fiber digestibility of the diets evaluated for the early cows and a 9% unit increase in digestibility for the mid-lactation cow data sets. Cows in early lactation fed high-fiber digestibility forages consumed 2.6 lb/day more DM ($n = 16$; $P < 0.004$) and produced 2.7 lb/day more fat-corrected milk **(FCM)** than cows fed the lower digestible forage diets. Dry matter intake **(DMI)** was not affected by forage digestibility for mid-lactation cows. Differences in fiber digestibility effects on DMI may be related to stage of lactation. When cows were in negative energy balance, intake was found to be controlled by physical fill when high forage diets were fed (Dado and Allen, 1996). Level of NDF concentration in a diet is negatively correlated to DMI since fiber ferments slowly and stays in the rumen longer than other feed components. However, fiber that is more digestible might stimulate intake as it disappears from the rumen, creating space for another meal sooner. The DMI of mid and late lactation cows, however, is less likely to be limited by physical fill but more by the ability of the metabolic processes of the cow to utilize absorbed nutrients for productive purposes. Therefore, depending on production level, mid and late lactation cows would be expected to respond less to an increase in DMI due to an increase in fiber digestibility (Robinson and McQueen, 1997). Allen and Oba (1996) demonstrated from these studies that a one unit increase in NDF digestion resulted in a 0.51 lb/day increase in milk yield.

More recently Grant (2004) fed cows diets containing forage with 58% NDF digestibility and cows produced 76 lb/day of milk, while cows fed a higher digestible NDF forage (67%) produced only 78 lb/day. When the high producing cows (i.e., >80 lb/day) were separated out, these cows actually produced an additional 6 lb/day of milk when provided the higher digestible NDF forage versus cows producing less than 60 lb/day of milk. Therefore, knowing information regarding forage digestibility is critical as it allows producers the opportunity to allocate higher digestible forages to higher producing cows and accordingly plan harvesting and storage structures.

Forage source will also impact forage allocation to other groups of animals on the farm. Sutherland (1988) demonstrated that as much as half of the particles in the rumen are smaller than the largest particles in the feces. Particles that have low concentrations of fermentable fiber that ferment quickly, such as from alfalfa, might pass more quickly than particles that have more fermentable fiber, which ferment slowly, such as from grasses (Jung and Allen, 1995; Allen and Oba, 1996). If it is assumed that the ruminal retention time is affected by stage of lactation, an early lactation cow may have a ruminal retention for NDF of 30 hours, while that for a late lactation cow approximately 45 hours. The potentially digestible NDF fraction of alfalfa may be nearly digested in the rumen of an early lactation cow while that of grass may only be 65% complete. At lower ruminal retention times, legumes may have greater DM digestibility because of their lower NDF contents and lower NDF digestibility than grasses (Varga et al, 1990). Faster rate of digestion of the potentially digestible fiber for alfalfa may promote greater intake via faster passage rate. However, the grass may have greater NDF digestibility when fed to cows with longer retention times, such as late lactation or dry cows. Grasses, therefore, may have similar or greater digestibility than legumes when offered to cows with longer ruminal retention times. Forage inventories can be varied to accommodate animals in different physiological states, such as late lactation and dry cows or heifers.

Broderick et al. (2002) demonstrated that DM and nitrogen efficiency, and total tract NDF digestibility, were greater for diets containing ryegrass silage compared to alfalfa silage. However, apparent digestibility of acid detergent fiber **(ADF)** was greater for alfalfa than ryegrass, which led to greater DMI and milk yield for the legume silage. Apparent digestibility of the ADF averaged 63% for ryegrass vs. 43% for alfalfa; however, apparent digestibility of the digestible fraction of ADF was actually greater for alfalfa than ryegrass. This indicated that microbial attack of digestible alfalfa fiber proceeded more rapidly in the rumen, despite higher intakes and presumably greater rate of passage.

In Vivo Versus *In Vitro* or *In Situ* Forage Fiber Digestibility

Due to many confounding factors, it is likely that digestibility of forage fiber measured in vitro or in situ is a better indicator of the potential of forages to enhance DMI than NDF digestibility measured in vivo. The NDF digestibility is a function of the potentially digestible fraction and its rate of digestion and rate of passage. Digestibility of NDF measured in vivo is confounded by different retention times in the rumen, which can be affected by differences in DMI (Oba and Allen, 1999). In addition, exposure to acidic conditions in the small intestine and fermentation in the large intestine in vivo might reduce differences observed for fermentation by rumen microbes in vitro or in situ. For this reason, NDF digestibility measured in vitro or in situ is an important measure of forage quality and should be distinguished from NDF digestibility in vivo. In addition, there is great variability in the estimate of in vivo digestibility, as there are many methods that have been employed throughout the years in many research trials. These include total fecal collection, use of chromic oxide as a marker, indigestible ADF or NDF as a marker, and rare earths that have been sprayed on or adsorbed onto fiber or indigestible fiber (Church, 1993). Rarely is recovery of these markers measured.

There has been a great deal of attention paid to measurement of in vitro NDF digestibility of forages and various corn hybrids, especially in the last 5 to 8 years. In many cases, especially when evaluating NDF digestibility of corn hybrids other than brown midrib **(BMR)** varieties, NDF digestibility differences may vary only by 2 to 3 percentage units among hybrids. When considering the associative effects of feedstuffs and the discussion above regarding the difference in in vitro versus in vivo fiber digestibility, it is not surprising that a production response may not be observed on a farm when in vitro analyses may indicate a 2 to 3% differences in NDF digestibility. In addition, it is clear that grouping of animals can dilute out or enhance the performance or milk component response on the farm.

The use of *in vitro* or *in situ* estimates of forage fiber digestibility is useful and should be continued; however, they have their own limitations (Oba and Allen, 2005). It is important that in vivo estimates of forage fiber digestibility are not related back to in vitro measures. For example, in the data set used by Oba and Allen (1999), the in situ or in vitro forage fiber digestibility of the high NDF digestible forage was 62.9% and for the low NDF digestible forage 54.5%. In that same data set, in vivo estimates of total tract NDF digestibility were also provided and were 54.8 vs. 51.5% for the high versus low NDF digestible diets.

Fiber Requirements

Allen (1997) summarized several studies on the effect of NDF on ruminal pH and found that overall dietary NDF concentration was not correlated with ruminal pH. The concentration of NDF provided by forage as a percentage of DM had a strong positive relationship with ruminal pH. However, Allen (1997) also demonstrated that fermentability of the fiber portion of the ration was more critical to the amount of acid produced in the rumen than either changing forage NDF as a percentage of DM or total NDF of the ration. Differences in sources of NDF, particle size of the forage, source and amount of nonstructural carbohydrates **(NSC)**, and the interaction among those factors have a large influence on ruminal pH. Due to these and other factors, it is difficult to provide a single value for the minimum concentration of NDF in the ration required to maintain ruminal health. Studies to evaluate minimum fiber requirements of lactating dairy cows were conducted by Clark and Armentano (1993), Colenbrander et al. (1991), and Depies and Armentano (1995). Combined, these studies suggest that when alfalfa is the primary forage source and provides approximately 65 to 75% of the total dietary NDF and corn grain is the predominant starch source, diets with 25% NDF are acceptable and appropriate when the forage is not finely chopped. Few studies have evaluated the minimum amount of NDF needed with corn silage based diets. Similar results were obtained for milk yield when corn silage based diets varied in NDF content from 24 to 29% (Bal et al, 1997). The NDF from corn silage elicits similar or greater chewing times than alfalfa silage (Mertens, 1997). Therefore minimum amount of NDF needed to maintain rumen function when diets are based on corn silage is probably similar or slightly higher than for diets with alfalfa silage assuming particle size is adequate. Forage source along with other factors play an important role in determining fiber requirements of the lactating cow, and this is especially important in early lactation.

The formulation of diets based on NDF of the ration DM has been recommended because of the positive relationship between NDF and rumen fill and the negative relationship between NDF and energy density (Mertens, 1994). A large portion of the fiber in the diet of lactating dairy cows needs to come from forage to maintain rumen function, milk fat percentage, and overall animal health. Previous NRC (1989) recommendations to ensure adequate fiber intake were a minimum of 25 to 28% dietary NDF with 75% of it supplied from forage. Therefore, a minimum recommendation for forage NDF on a DM basis is 18.75% (25% NDF X 75% = 18.75% forage NDF). However, the percentage of dietary NDF from forage might not adequately reflect the presence of effective fiber when by-products feeds that are high in fiber are incorporated into the ration. Even when NDF from forage is used as an index of adequate fiber, particle size (Woodford and Murphy, 1988), and species of forage must be evaluated. When forages are harvested at different stages of maturity, this is especially evident. Hoffman et al (1993) demonstrated that the digestibility of NDF for legumes decreased approximately 20% from late vegetative to midbloom, rate of digestion decreased almost 35%, and the indigestible portion of the NDF increased 30%. The effect of forage maturity on DMI is presented in Figure 1.

Factors Affecting Fiber Digestibility

Fiber digestibility is usually defined as the proportion of ingested fiber that is not excreted in the feces. Fiber contains an indigestible fraction and one or more potentially digestible fractions, each of which is degraded at its own rate. The process of fiber digestion consists of hydrolysis of polysaccharides and the conversion of monosaccharides to volatile fatty acids **(VFA)**, fermentation gasses, and heat (Tamminga, 1993). The rate of hydrolysis is generally the limiting factor in fiber digestion in the rumen (Varga and Kolver, 1997). The rate of hydrolysis is limited by penetration of the enzymes that degrade the cell wall deep into lignin-polysaccharide complexes. The extent of fiber digestion depends on the size of the indigestible fraction and the competition between the rate of degradation and the rate of passage out of the rumen. Excellent reviews on factors affecting fiber rate and extent of fiber digestibility are available (Mertens, 1994 and 1997; Firkins, 1997; Allen, 1997).

The indigestible fraction of NDF is a major factor affecting the utilization of carbohydrate sources as it varies greatly and may exceed more than one half of the total NDF in the rumen. Glenn and Canale (1990) demonstrated that particulate matter leaving the rumen has a high ratio of ruminally undigestible fiber to digestible fiber. They proposed that the rate grass and legume cell walls reach this ratio might serve as a regulator of particulate turnover from the rumen. Although information on the size of the indigestible fiber fraction of some forages are available, information is still needed on other nonforage fiber sources **(NFFS)**, as well as on the portion of the potentially digestible fraction that is actually digested. The rate at which the potentially fermentable NDF is fermented is another major factor affecting fiber utilization. Though most forages are higher in fiber content than NFFS, some forages can be digested at higher rates than some NFFS (Firkins, 1997). Therefore, replacement of forage sources, such as very high quality alfalfa haylage, for NFFS to reduce fermentation rate in the rumen has advantages.

Varga et al. (1984) fed diets to early lactation cows that were formulated to be low or high in fiber fill value and that had been formulated to differ in rate and extent of NDF digestion. Although cows produced significantly more milk and milk protein on the low fill diet and had almost two-fold fewer kilograms of DM in the rumen, they did not consume more feed than the cows fed the high fill diet. Robinson and McQueen (1997) observed when mid lactation cows were fed forages of varying fermentability and level of concentrate, cows responded by increasing DMI and milk production. The variation in the outcome of these studies can be related to a combination of factors. Milk production potential of the cows was different as was the forage fiber and NFFS used in the rations. In addition, the physiological state of the cows differed. Finally, maybe the most important factor still unknown is the contribution of the indigestible fiber pool on intake, as well as the digestibility of the potentially digestible pool. The main reason for lack of an effect on DMI is probably that small particle potentially digestible NDF may not promote rumination activity and therefore retains much of its bulk characteristics and contributes to rumen fill. Additional research is needed to measure the contribution of forage fiber and various NFFS to total chewing activity and bulk in the rumen and their impact on forage fiber digestibility.

A great deal of attention is paid to in vitro and in situ NDF digestibility information of forages that may have NDF concentration between 35 to 40% on a DM basis. Perhaps as much, if not more, attention should be placed on the other components that clearly contribute energy and protein to the ration. As an example, Varga et al. (1990) and Aldrich et al. (1996) determined the in situ disappearance of all feed ingredients for fiber, starch, and protein of the TMR fed to cows. Using this information on individual feed ingredients allowed for closer prediction of whole animal diet digestibility.

Interaction of Concentrates and Nonforage Fiber Sources on Forage Digestibility

Ruminal fiber digestibility is also affected by the rate of passage of particulate matter out of the rumen. Rate of passage is affected primarily by intake. However, feed particle size, concentrations of dietary fiber and NSC level, and rate of digestion of the potentially digestible fiber fraction may also affect passage rate. Interference of NSC with fiber digestion has been observed frequently, and the main effect is a drop in ruminal pH with a negative effect on fiber digestion (Tamminga, 1993). The effect of starch on fiber digestion does vary with starch source. Replacing corn with barley has been shown to have a negative effect on fiber digestibility (McCarthy et al., 1989; Herrara-Saldana et al, 1990). When the starch sources, cassava, barley and corn, were studied, cassava and barley starch sources had more of a pronounced effect on the amount of fiber in the rumen over time after feeding (Tamminga, 1993). Apparent digestibilities of fiber were 55.1 and 56.3% for barley and cassava-containing diets, respectively, and 63.6% for the corn-containing diet. Concentration and type of NSC will affect the rate of passage of potentially digestible fiber from the rumen. Many experiments have also shown that NFFS forage sources, such as beet pulp, almond hulls, citrus pulp, and cottonseed, have a positive effect on fiber digestion as fiber concentration in the ration is increased using these fiber sources.

Adding sugar as dried molasses (2.4 to 7.2% total sugar) to diets formulated to contain 60% forage on a DM basis (65% corn silage and 35% alfalfa haylage) resulted in a 4% unit increase in total tract NDF digestibility in Holstein dairy cows (Broderick and Radloff, 2004). In the same paper when adding liquid molasses to provide 2.6 to 10% total sugars, these authors observed an 8% unit increase in NDF total tract fiber digestibility. Sugar source and amount can affect fiber digestibility. Sugar addition to the diet has been shown to enhance fiber digestibility, especially for poorer quality forages (Varga, 2003).

Grinding and pelleting usually results in decreased rate and extent of ruminal fiber digestion (Shaver et al., 1988; Uden, 1988). Although grinding increases the surface available for microbial attack, retention time of the particles is reduced, and the net result is often reduced total tract digestibility. Grinding and pelleting results in an increase in the size of the calculated undegradable fiber fraction and an increased length of the lag phase (Tamminga, 1993). Reduced ruminal pH caused by a decrease in rumination reduces production and flow of saliva which impacts ruminal fiber digestibility by the cellulolytic organisms (Shaver et al., 1988).

Effects of Forage Particle Size on DMI, Digestibility, and Milk Yield

Few authors have observed particle size effects of alfalfa silage on DMI when well balanced rations were fed to mid-lactation cows. Positive effects with reduced particle size on DMI have been reported in some studies feeding corn silage of different particle sizes (Stockdale and Beavis, 1994) but have not been observed in others. Positive effects with reduced particle size have been observed when poor quality forages containing high cell walls were fed (Kusmartono et al., 1996). Although several authors have reported increased DMI with reduced forage particle size while feeding high quality forages (Beauchemin et al., 1997), most authors report no effect on DMI when good quality forage is fed. Taken together, most reports support the hypothesis that DMI is influenced by particle size reduction only when a poorly digestible feed with a high cell wall content is fed, and no effects occur when good quality forages are fed.

For alfalfa based diets, forage particle size has been shown to significantly affect both yield and composition; however, most differences are reported when forage is in the dehydrated form (Shaver et al., 1988; Woodford and Murphy, 1988). When forage is in silage form and different lengths of cut are fed, differences have been observed in milk fat (Shaver et al., 1988; Grant et al., 1990; Fisher et al., 1994) and protein percentage (Beauchemin et al., 1994). No effect of particle size on milk components was observed by Colebrander et al. (1991) when altering forage particle size.

Fiber Sources

Various NFFS, such as soybean hulls, beet pulp, corn gluten feed, whole linted cottonseed, dried distillers grains, and wheat middlings, have been used in the diets of lactating cows to supplement conventional forage fiber. Many of these contain more NDF than some forage sources (Firkins, 1997). One of the major differences between nonforage and forage sources of NDF is particle size. Although differences exist among feedstuffs, nonforage fiber is less effective at maintaining good chewing activity and ruminal health compared with forage fiber of adequate particle size. Allen (1997) demonstrated that NDF from forage was 2.8 times more effective at increasing pH than was NDF from nonforage sources. Firkins (1997) concluded that forage fiber was about 1.6 times more effective at maintaining total tract fiber digestibility than was nonforage fiber. Based on chewing activity, Mertens (1997) presented information that forage NDF was approximately two fold more effective at buffering the rumen environment than nonforage NDF. Therefore, when forage NDF is replaced by nonforage NDF, it is on the average 50% as effective in stimulating chewing activity and/or milk fat percentage as that of forage NDF. For a diet based on forage with adequate particle size and dry corn, the minimum NDF should be 25% total NDF with 75% of the NDF from forage (approximately 19% of dietary DM). A method to calculate minimum concentrations of total NDF and forage NDF and maximums for nonfiber carbohydrates **(NFC)** is presented in the dairy NRC (2001).

What Do We Know About In Vivo Forage Fiber Digestibility for Dairy Cows?

First of all, forage NDF is needed in diets to maximize milk yield, efficiency of feed utilization, and animal health. Forages provide longer particles than other feed ingredients, which are needed to form a rumen mat that entraps smaller particles, thus increasing their digestibility (Allen, 2005). Forage NDF is retained in the rumen longer and is therefore more filling than other feed components. High yielding cows are challenged to meet their energy requirements, and DMI of these cows is limited by the filling effects of diets to a greater extent than for low yielding cows consuming the same diet. Therefore, a greater advantage might be expected for forages with high NDF digestibility when included in high forage NDF rations. Gut fill is more of a limitation to DMI as diet forage NDF concentration increases. Enhanced NDF digestibility of BMR corn silage compared to its isogenic control led to an increase in DMI and milk yield to a greater extent when fed in higher forage (39% NDF) compared to lower forage (29% NDF) diets (Oba and Allen, 2000).

There is some concern, however, when digestibility of forages is improved, as many dairy rations are already formulated for minimum dietary NDF and forage NDF content (25 and 19%, respectively; NRC, 2001) and contain 50% or greater highly fermentable carbohydrates. Therefore, increasing the digestibility of the forage fraction and/or increasing the amount of highly digestible forage into the ration could increase the problem observed when feeding higher concentrate diets. Therefore, a high NDF corn silage might be beneficial if the increased NDF did not limit intake through decreased NDF digestibility and rumen fill. Higher NDF corn silage would allow for a greater incorporation of forage into the ration. Ivan et al. (2005) nicely demonstrated the benefits of replacing a corn hybrid with high NDF and high NDF digestibility for a hybrid with lower NDF and lower NDF digestibility on DMI, milk yield and digestibility in lactating dairy cows. These researchers demonstrated an increase in DMI, milk yield, and total tract NDF digestibility for high NDF corn silage with a high NDF digestibility compared to the low NDF corn silage with a low NDF digestibility. It has been thought that increasing the NDF content of the diet, as was the case for the high NDF corn silage hybrid, would decrease passage rate of the diet, but apparently the higher rate of NDF digestion in the rumen was able to overcome the presumed decrease in passage rate due to higher NDF concentration (Shaver et al., 1988). The wet digesta weight, ruminal volume, and digesta DM and NDF were all lower for the higher NDF diet, indicating that higher NDF digestibility of this diet was decreasing ruminal fill. This all agrees nicely with the data of Broderick et al. (2002) when they compared alfalfa versus ryegrass silages fed to lactating dairy cows.

Fiber digestibility can be affected by forage source, as well as fermentability of other carbohydrate sources in the ration (i.e., corn). A study recently completed by Brown et al. (2006; Table 1) formulated diets to contain 50% of the ration DM as forage, of which 50% was made up of either alfalfa or grass silage and the remainder as corn silage. Within each forage source, either fine ground corn or coarse corn was evaluated for effects on milk yield and components and nutrient digestibility. Dry matter intake and FCM were significantly higher for the alfalfa silage based diets. However, apparent NDF digestibility was not different between forage sources but was enhanced when corn was finely ground. In situ NDF digestibility was 40% lower for the grass silage, while in situ digestibility of the total mixed diets were not different among treatment and reflected the data observed for apparent NDF digestibility. Though not measured, it is possible, based on previous discussions, that rate of fermentation, rate of passage, rumen fill, and ultimately DMI affected milk yield.

Conclusions

In addition to careful selection of corn silage hybrids for lactating dairy cows, source of forage and level of incorporation into the dietary DM are important areas needed for future research. The inclusion of greater quantities of high quality forages into lactating cow rations is justified and can be accomplished using forage analyses and digestibility information. However, the interaction of level of forage inclusion, forage source, DMI, concentrate sources, and how they are processed clearly impact forage fiber digestibility. Due to many confounding factors, it is likely that digestibility of forage fiber measured in vitro or in situ is a better indicator of the potential of forages to enhance DMI than NDF digestibility measured in vivo. Digestibility of NDF measured in vivo is confounded by different retention times in the rumen, which can be affected by differences in DMI. In addition, exposure to acidic conditions in the small intestine and fermentation in the large intestine in vivo might reduce differences observed for fermentation by rumen microbes in vitro or in situ. For this reason, NDF digestibility measured in vitro or in situ is an important measure of forage quality and should be distinguished from NDF digestibility in vivo.

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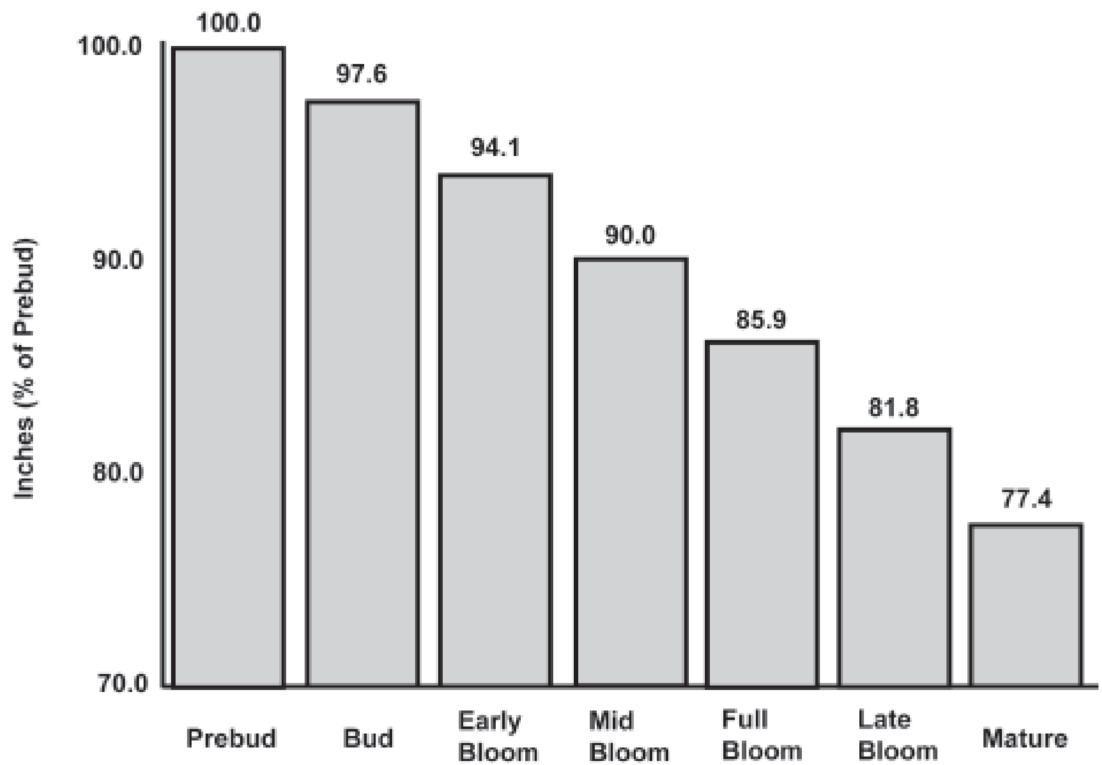
Table 1. Effect of alfalfa versus grass silages with coarse or fine ground corn in diets for lactating dairy cows on DMI, FCM, milk components, and nutrient digestibility.[1,2]

Item	Alfalfa Fine Corn	Alfalfa Coarse Corn	Grass Fine Corn	Grass Coarse Corn	Significant effect
DMI, lb/day	61.4	61.4	48.6	48.4	Forage effect
FCM, lb/day	80.7	77.2	64.5	67.5	Forage effect
Milk fat, %	3.66	3.85	3.75	3.71	NS
Milk protein, %	3.11	3.09	3.07	3.03	Forage effect
Apparent DM digestibility, %	57.6	57.3	60.0	52.9	Forage X Corn
Apparent NDF digestibility, %	32.6	29.0	36.9	29.4	Corn effect

[1]Taken from Brown et al. (2006).
[2]DM = dry matter, DMI = dry matter intake, FCM = fat corrected milk, NDF = neutral detergent fiber, and NS = not significant.



Adapted from Hibbs and Conrad. 1974. Ohio Report 59(2):33.

Figure 1. Effect of alfalfa-brome greenchop stage of maturity on dry matter intake.