Better Understanding Forage Fiber and Digestibility

David Combs

Professor, Department of Dairy Science, University of Wisconsin-Madison

Take-Home Messages

Forage utilization by high producing ruminants is greatly affected by NDF digestibility.
Three fiber parameters must be measured to quantify NDF digestion: The proportion of NDF that is potentially digestible, the rate of ruminal degradation of the potentially digestible fiber, and the rate of passage of potentially digestible fiber.

Single time point in vitro NDFD assays are not accurate indicators of fiber digestibility and have limited utility in forage evaluation.

A new in vitro forage test (TTNDFD) is proposed as an alternative to single time point NDFD assays.

Introduction

Plant fiber is a complex material whose digestibility varies due to forage species, forage variety, plant maturity, and growing environment. Neutral detergent fiber (NDF) is a forage test that measures the total amount of fiber in a feed. We've known for a long time that NDF represents a 'bulky', slow-to-digest feed component which can restrict feed intake and energy utilization. While this is a critical measure of feed quality, it only reveals part of the story about fiber. In order to optimize the utilization of forages by ruminants, fiber digestibility and the rate at which fiber digests must also be accounted for because both greatly affect feed intake and production. Fiber digestibility is more variable than the digestibility of any other feed component and fiber accounts for 30 to 40% of the digestible energy (DE) in high quality forages.

Wisconsin research and extension have been leaders in developing tools that farmers, nutritionists, and agronomists use to index or compare forage quality within forage type. Relative forage quality (RFQ) for legumes (Undersander and Moore, 2002) and milk per acre and milk per ton (Schwab et al., 2003) for corn silage are widely used tools that utilize forage NDF and NDFD to compare alfalfa varieties and corn silage hybrids, respectively. Fiber digestibility in these equations is estimated from 30 or 48 h in vitro NDFD measurements. These indexes can't be used to compare forages across types however, which limits their value as decision-making tools for optimizing the combination of corn silage, alfalfa co-product feed and grass in dairy systems. The objective of this presentation is to present a new approach to measure and predict fiber digestion which can be used in ration evaluation and formulation.

Quantifying Fiber Digestion

Fiber digestion occurs primarily in the rumen and is the result of a dynamic process that is affected by the chemical nature of the plant fiber and by the digestion and passage of fiber within the animal's digestive tract. The chemistry of NDF affects the rate of fiber digestion (Kd) and the proportion of NDF that is potentially digestible (pdNDF) (Mertens, 2002). Rate of passage of fiber (Kp) is primarily affected by level of intake of the animal and by its indigestible fraction. Digestible NDF is selectively retained in the rumen (Lund et al., 2007). Fiber digestibility is ultimately the result of the interaction of Kd and Kp and can be described mathematically as:

Proportion of potentially digestible fiber digested =pdNDF x ((Kd)/ (Kd + Kp)) (Mertens, 2002).

In the most simple model, the kinetic parameters needed to estimate ruminal fiber digestion include an estimate of the proportion of fiber that is potentially digestible (pdNDF), the rate of digestion of the potentially digestible fraction, and the rate of passage of the potentially digestible portion of NDF.

Measuring ruminal fiber digestion in vivo is laborious and expensive, but is the 'gold standard' to which other methods should be compared. In vivo fiber digestion kinetics is most commonly measured by the 'rumen evacuation' technique (Taylor and Allen, 2005, Huhtanen et al., 2007, Ivan et al., 2005). This method is carried out with ruminally-cannulated animals. Rumen pools of digestible and indigestible fiber are measured by total rumen evacuation and fiber flow from rumen is estimated using external markers and spot-sampling digesta from the omasal orifice or from intestinal cannulas (Huhtanen et al., 1997). Reliable estimates of ruminal digestion and passage require that the animals be in steady state so that rumen fill varies minimally throughout the course of the day. This is achieved by feeding cows frequently and monitoring daily feed intake to ensure that day-to-day variation in feed intake is minimal (Huhtanen et al., 2007). Despite the cost there are a relatively large number of rumen evacuation studies that have been done in the US and Northern Europe. Krizsan et al. (2010), published a meta-analysis of ruminal passage rates of indigestible NDF in cattle based on the rumen evacuation technique. Their database included 49 studies in which 172 treatment means were measured. Huhtanen et al., (2010) also published a meta-analysis of NDF digestion using the rumen evacuation method and omasal sampling. Thirty-two studies and 122 diets were included in this analysis. Most of the published studies are with lactating dairy cattle fed grass, alfalfa or corn silage based diets.

Estimating Rumen Fiber Degradation from in vitro NDFD Values

Taylor and Allen (2005) reported that the rate of ruminal digestion of potentially digestible NDF from normal and BMR corn silages varied from 2.7 and 3.3% per hour when measured by the rumen evacuation technique. These values are consistent with ruminal digestion rates estimated by Ivan et al. (2005) in corn silages when measured by ruminal evacuation method and by Greenfield et al. (2001) who measured corn silage fiber digestion kinetics in lactating cows that were surgically fitted with rumen and duodenal cannula. In some of these studies, 30-h or 48-h in vitro NDFD values were reported for the forages used. However, in vitro rates of fiber degradation were not reported or compared to the in vivo measurements.

In vitro and in situ methods are widely used as an alternative to in vivo methods for estimating and comparing rumen fiber digestion. In vitro and in situ techniques measure relative, not absolute fiber digestion. Oba and Allen (1999) reviewed several feeding studies with dairy cattle and concluded that a 1% change in vitro or in situ NDF digestibility was correlated with a 0.17 kg increase in voluntary dry matter intake, and 0.25 kg increase in 4% fat corrected milk yield. The change in situ or in vitro fiber digestibility within a study was correlated with intake and milk production, but there was no significant correlation between the absolute measures of fiber digestion and intake or milk yield across studies.

The NRC (2001) suggests that a 48-h in vitro NDFD can be used as the NDF digestibility coefficient to calculate digestible NDF for forages at maintenance intake. At maintenance intake, rate of passage will be relatively low, which will minimize the effect of rate of fiber degradation on fiber digestibility. Adjusting fiber digestibility for cows at higher levels of intake was not directly addressed in the Dairy NRC (2001), rather the NRC adjusts the TDN value of the entire forage. Digestion rates of potentially digestible NDF can vary from less than 2% per hour to over 6% per hour. As intake and rate of passage increase, depression in fiber digestibility due to passage would be more pronounced in the forages with lower fiber digestion rates. The 48-h in vitro NDFD value does not accurately reflect the rate of fiber digestion.

Another problem with single time point in vitro NDFD assays is that the value is not a direct measure of pdNDF, or rate of fiber digestion. A single time point in vitro NDFD assay simply indicates how much residual fiber remains after a specific time period of exposure to rumen fluid. The residue measured includes the indigestible fiber fraction plus the residual potentially digestible fiber remaining. A hypothetical example can demonstrate the shortfalls of comparing fiber digestibility based on a single time point NDFD assay. In Table 1 are the digestion kinetic parameters of two forages with similar concentrations of NDF (40%). The two forages differ however in size of the pdNDF fractions and the rates at which the pdNDF digests. Forage A has a higher indigestible NDF fraction than Forage B, but the rate at which the pdNDF digests is faster in Forage A than in Forage B. If the pdNDF in both forages were to pass at the same rate (2.7%/h), ruminal and total tract digestibility would be similar for the two forages. The expected in vitro NDFD values can be calculated if one assumes simple first order degradation of pdNDF in a closed system (Figure 1). The figure demonstrates that Forage A, with a higher indigestible fraction and relatively fast rate of degradation of pdNDF will have higher NDFD values at short incubation times. As incubation times increase, the NDFD values of Forage B with the slower rate of digestion, but higher proportion of pdNDF become greater than the NDFD values of Forage A. Ruminal and total tract digestion of the two forages are equal, which suggests that the DE values of Forage A and B are the same.

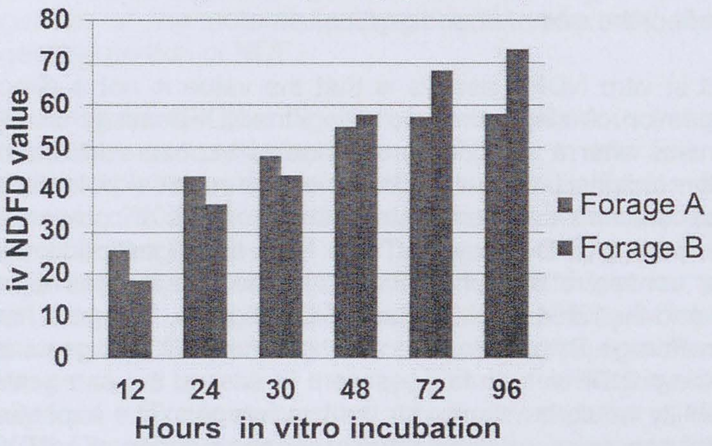
Table 1. Predicted in vivo digestion of fiber from two forages with different pool sizes and rates pdNDF degradation when rate of passage (kp) is assumed to be .0267/h.

Item	Forage A	Forage B
iNDF, iv 240 h fraction	0.42	0.22
kd pdNDF, %/h	6.5	3.0
kp pdNDF, %/h	2.7	2.7
Rumen digestion*		
NDFD, % of NDF	41	41
Total tract digestion**		
NDFD, % of NDF	46	46

*Calculated as 100 – (iNDF + (pdNDF x kd/(kd +kp)))
** Assumes 10% of NDF digestion occurs in the hindgut.

None of the in vitro single incubation time points accurately reflect how these two forages would be utilized by the animal because none of the time points chosen in the lab assay reflect the mean retention time of the forages in vivo. The values of iNDF, or kd of pdNDF in themselves also do not accurately reflect the potential digestibility of NDF or the DE value of the forage. The most useful value will be one that uses the digestion kinetic parameters to calculate a digestibility coefficient for NDF. The coefficients of ruminal or total tract NDF digestibility account for iNDF, kd of the pdNDF and kp of pdNDF and therefore more accurately reflect how forage fiber will be utilized by the animal.

Figure 1. Expected in Vitro NDFD values for Forage A (40% NDF, kd=6.5%/h, iNDF=.42) and Forage B (40% NDF, 3.0 %/h, iNDF=.22)



The proportion of fiber that is potentially digestible varies considerably within forage type, which means that it is important to account for iNDF, and kd of pdNDF when comparing one corn silage to another or one alfalfa to another. Within our lab the iNDF fractions in alfalfa and grasses vary from less than 5% to over 55% of NDF, while corn silage iNDF values range from less than 10% to over 40% of NDF (unpublished data). Krizsan et al. (2010) reported that iNDF values in a database of 172 feeds ranged from 2.4 to 17.4% of feed dry matter. In addition the estimated rates of degradation of pdNDF vary from about 1% per hour to over 10% per hour when measured by using multiple incubation time points and fitting the disappearance of pdNDF to first order kinetics. These data suggest that a single NDFD30 or NDFD48 hour value, as commonly reported on forage test reports provide little useful information regarding fiber digestibility.

Van Amburgh et al. (2003) recognized the limitations of individual NDFD time point values and proposed a mathematical procedure to calculate rates and extent of NDF degradation from a single time point in vitro fermentation measured between 24 and 30 h. Their objective was to develop a means of predicting rates of NDF digestion that could be used in the Cornell-Penn Miner (CPM) dairy program. In their kinetic model, the rate of fiber disappearance was calculated by assuming a constant lag time for their in vitro system, and fixing the indigestible NDF fraction as 2.4 * lignin. Their approach used the log transformations of the residual pdNDF at 0hr, the measured NDFD value and the indigestible NDF fraction to construct a model to describe fiber degradation as it would occur if there were slowly digesting and rapidly digesting pools of pdNDF. The proportion of NDF in the fast and slow pools and their rates were then mathematically combined to derive a weighted average rate of fiber degradation. The weighted kd value was then used with an empirical estimate of forage dry matter passage to predict ruminal fiber digestibility. The model to predict rates of pdNDF degradation was tested against in vitro degradation curves generated from multiple incubation time points and from degradation curves derived from in vitro gas production. The calculated rates of NDF digestion were not compared to directly measured in vivo rates of fiber degradation. Raffrenato and Van Amburgh, (2010) more recently proposed that a more precise and accurate weighted average rate of NDF degradation could be achieved by using 36 h and 120 h in vitro NDFD values and using a long term (240 h) in vitro NDFD to determine the indigestible NDF fraction. This approach again has been validated by comparing the rates of NDF digestion from this model against in vitro degradation curves derived from multiple incubation times. The fiber degradation rates derived from these approaches are then coupled with predicted rates of forage DM passage in the Cornell Net Carbohydrate and Protein System (CNCPS) to predict fiber digestion.

The CNPCS model and NRC dairy use the passage of forage DM, not pdNDF, to estimate fiber passage. The passage rate of forage DM is higher than the passage of pdNDF (Hutanen et al., 2009; Allen, 2011). The over-estimate of kp appears to be compensated for by what appear to be over-estimates in the rates of NDF degradation. Raffrenato and Van Amburgh (2010) reported that the average composite rates of pdNDF degradation for corn silage was approximately 6% per hour for normal corn silage and 7.8% per hour for BMR corn silages, and 11.3% per hour for alfalfas. These kd values are one and half to twice as high as kds for similar forages when measured in vivo by rumen evacuation. Results from the meta analysis of Krizsan et al. (2010) found that the fiber degradation rates used in the NRC dairy model and the CNCPS are higher than those measured in vivo.

Allen (2011) also suggests that fiber digestion determined from in vitro methods (traditional in vitro method) over-estimate in vivo fiber digestibility. In many labs, the over-estimation of the kd's for potentially digestible NDF could be due to how the in vitro assay has been modified to improve precision. The in vitro NDFD values at any given time point are affected by particle size and grind type, amount of sample used, the buffering capacity of the in vitro system. It is widely known that in vitro NDFD values vary from lab to lab because most labs have modified the original Goering and Van Soest (1970) method.

TTNDFD

University of Wisconsin researchers have recently proposed a more direct model of fiber degradation that could be used by field nutritionists. The outcome is a total tract digestibility coefficient for NDF (TTNDFD). The TTNDFD value is benchmarked to fiber digestibility values that have been obtained from feeding studies where NDF digestion has been directly measured. Total tract fiber digestibility is reported because this value can be used in equations to predict forage DE, NE or TDN values. The approach accounts for ruminal and post-ruminal fiber digestion and can be adjusted for changes in fiber passage as size or intake of the animal changes. Multiple measurements of in vitro NDF digestibility are used to calculate a rate of ruminal NDF digestion for a feed (Goeser and Combs, 2009). The NDFD measurements can be done in the lab with in vitro analysis or by near infrared spectroscopy (NIR). The ability to rapidly predict TTNDFD of forages from NIR is critical to field nutritionists.

Field Observations with the TTNDFD

We have been monitoring the TTNDFD values of corn silages, alfalfa and grasses that have been submitted to a commercial forage testing lab for routine analysis. The TTNDFD values for corn silage, alfalfa, and grasses are summarized below. The average values represent over 7000 samples each of corn silage or alfalfa and over 1200 grass forage samples.

Table 2. Typical TTNDFD values of corn silage, alfalfa or grass*.

	Mean	SD	Mean – 1 SD	Mean + 1 SD	Range
	----------------------------	TTNDFD©, % of NDF	----------------------------		
Corn Silage	42	± 6	36	48	20-60
Alfalfa	43	± 7	36	50	25-80
Grass	47	± 8	39	55	6-80

Samples submitted to Rock River Laboratories, Watertown, WI.

The means, standard deviations (SD) and ranges in TTNDFD© values coincide with in vivo measures of total tract NDF digestibility that have been reported in dozens of controlled feeding studies published in peer reviewed journals. Goeser (2008) summarized total tract fiber digestibility measurements that were reported 25 corn silage feeding trials (81 treatment comparisons) and in 20 trials in which legumes and grasses (64 treatment comparisons) were the primary forages fed to high producing ruminants (Table 3). A more recent survey of literature of corn silage based feeding trials (Ferraretto and Shaver, 2012) reported that the treatment means for total tract NDF digestibility averaged 44.3 ± 2.5 % in 106 treatment observations from 24 dairy feeding trials that were published in peer-reviewed journals between 2001 and 2011. Huhtanen et al (2010) reported that total tract NDFD averaged 59.4 ± 12 % in 32 studies with 118 treatment observations. This database included studies in which corn silage, grass silage, and alfalfa silages were fed to beef cattle as well as dairy cattle. The average DMI of from these studies were relatively low (19.1 kg/d) compared to intakes in the databases collected by Goeser (2008) and Ferraretto and Shaver (2012). Summary statistics from the published studies suggest that in vivo NDF digestibility coefficients can vary by 30 to 35% units among legumes, grasses and corn silages. It also is apparent that ruminants do not fully compensate for different rates of fiber digestion (kd) by adjusting their voluntary DMI to alter passage (kp) of potentially digestible fiber. Therefore, an estimate of total tract fiber digestibility can provide useful information about fiber utilization.

Table 3. Total tract NDF digestibility coefficients reported in peer-reviewed feeding studies (Goeser, 2008).

		In vivo total tract NDF digestibility
Legume/grass feeding trials	Mean	47.3 % of NDF
(20 trials, 64 treatment observations)	Median	47.5 % of NDF
	Range	31.1-66.2 % of NDF
	St. Dev	8.1
Corn Silage/Sorghum feeding trials	Mean	40.2 % of NDF
(25 trials, 81 treatment observations)	Median	41.1 % of NDF
	Range	20.1-58.8 % of NDF
	St. Dev.	8.8

BMR Corn Silages and TTNDFD

BMR-corn silages have more highly digestible fiber than conventional corn silages. Corn hybrids with the BM3 mutant have lower lignin and a lower proportion of iNDF than isogenic normal corn silages. Oba and Allen, (1999b) reported that the in 30 h IVNDFD for a BM3 corn silage was 9.5% units higher than its isogenic control but when the BMR corn and its isogenic control were fed to lactating cows the diets differed in total tract digestibility by approximately 2% units. Data from our lab (unpublished) indicates that on average, BMR corn silages are approximately 5 units higher in TTNDFD than conventional corn silages if they are compared at equal feed intakes and 2-3 units higher in NDF digestibility if DMI intake (and subsequently kp of pdNDF) is increased by 5 to 7 %. A 5 to 7% increase in intake is consistent with the change in intake observed in feeding studies summarized by Oba and Allen (1999a).

Allen and Oba (2009b) suggest that the improvement in fiber digestibility with BMR lines is largely due to the reduction in the proportion of indigestible fiber. The TTNDFD test indicates that improved fiber digestion in BMR hybrids is the result of a lower proportion of iNDF but that the rate of fiber digestion is also increased. The TTNDFD test also reveals that there is considerable overlap in fiber digestibility between conventional and BMR corn silages, which suggests that growing conditions, time of harvest and other factors beyond plant genetics also affect plant fiber digestibility. These observations are also consistent with what has been directly measured in controlled feeding experiments (Oliver et al., 2004, Allen and Oba, 1999, Ivan et al., 2005).

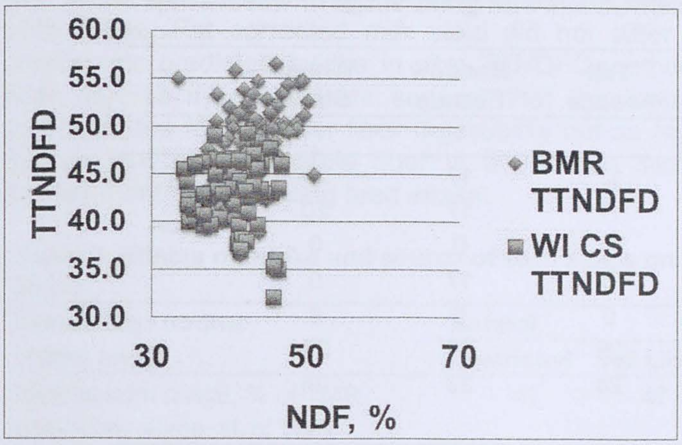


Figure 2. TTNDFD values reported for corn silage samples identified as BMR and corn silage not specifically identified as BMR. Samples were submitted to a Wisconsin forage testing lab by dairy consultants.

Validating the TTNDFD Approach

We recently completed a series of feeding trials to test and validate the TTNDFD approach. The objective of the first study (Verbeten et al., 2012) was to test the concept that forages with more highly digestible fiber could effectively replace fiber from corn silage and alfalfa. A control diet was formulated with excellent quality corn silage (30.5% DM, 37.5% NDF) and alfalfa silage (44% DM, 36.5% NDF) as the only sources of forage (Table 4). Grass silages were used in test diets to replace one third of the corn silage and alfalfa. One diet was formulated with tall fescue silage (51% DM, 50.1% NDF) and another diet was formulated with meadow fescue silage (38.5% DM, 50.1% NDF). Another diet was formulated with wheat straw (92.1% DM, 79.9% NDF). Wheat straw replaced an equivalent amount of NDF as the diets with the grass silages. Replacement of one third of the corn silage and alfalfa mix with the grass silages raised the diet NDF content, and increased the total tract NDF digestibility. Cows fed the diets including grass silages produced similar levels of milk as compared to the control diet. The fiber digestibility of the diet containing corn silage and alfalfa was 25%. The NDF digestibility was increased to over 40% by replacing about a third of the corn silage and alfalfa by either tall fescue silage or meadow fescue silage. Adding wheat straw increased the NDF content compared to control, but did not alter total tract fiber digestibility. The additional fiber improved milk fat percentage for all three test diets, but it appeared that fat test was improved more when the fiber was from the more highly digestible fescues than from wheat straw. Partial replacement of corn silage and alfalfa fiber with more digestible fiber from grasses increased total tract digestibility of NDF and improved milk fat test without reducing milk production. This trial demonstrates that diets can be formulated to improve fiber utilization if fiber digestibility could be measured.

A second study (Lopes et al., 2013) was designed to compare estimates of ruminal fiber digestion predicted from in vitro NDFD analysis of feeds to the ruminal fiber digestion measured in cattle fed the same feeds. The in vitro TTNDFD model predicts rumen fiber digestibility from the rate of pdNDF degradation (kd), the rate of passage of pdNDF (kp) and the proportion of total NDF that is potentially digestible. The kd is calculated from in vitro NDFD measurements taken at 24, 30 and 48 h of incubation using first order kinetics model with an indigestible fraction (Mertens, 1993). Passage of potentially digestible fiber is predicted from a regression model (Krizsan et al., 2010) for iNDF which is adjusted to account for the selective retention of pdNDF (Lund et al., 2006). The pool of indigestible fiber was estimated from 288 h in situ NDF residues. In this model, the NDF and the TTNDFD value for each feed used is calculated and the NDF and TTNDFD content of the diet is calculated from the values for each feed.

Table 4. Partial replacement of corn silage and alfalfa with grass silage or wheat straw (Verbeten et al., 2012).

	CS/ALF	Tall Fescue	Meadow Fescue	Wheat Straw	
Diet component*, % of DM					
Corn silage	26	17	17	20	
Alfalfa silage	26	17	17	20	
Tall fescue silage	0	17	0	0	
Meadow fescue silage	0	0	17	0	
Wheat straw	0	0	0	8	
High moisture corn	26	25	26	24	
Protein/minerals	22	24	23	28	
Diet composition					
NDF, % of DM	24.2	27.1	27.3	27.6	
Results					**SE**
DM Digestibility	62.6[b]	64.9[ab]	67.4[a]	62.2[b]	1.1
NDF digestibility*	25.2[b]	40.5[a]	41.1[a]	29.1[b]	2.2
DMI, lb/d	58[ab]	54[b]	59[a]	58[ab]	1.1
Milk fat, %	2.9[a]	3.4[b]	3.4[b]	3.2[ab]	0.1
3.5% FCM, lb/d	91	92	95	92	2.1

The feeding study was conducted with lactating dairy cows fed either normal corn silage or BMR corn silage as the main source of dietary NDF at ad libitum or restricted (90% of ad libitum) intake (Table 5). The fiber characteristics of the normal corn silage (34.4% NDF, iNDF 41.4% of NDF, kd 3.2%/h) and the BMR corn silage (38.4% NDF, iNDF 25.7% of NDF, kd 3.3%/h) were determined prior to the feeding experiment. The fiber characteristics of the two silages were then used to predict ruminal NDF digestibility of the treatment rations. The predictions for each diet were then compared to the observed measures of fiber digestion. The in vitro method predicted that the BMR corn silage was higher in NDFD than the normal corn silage because it contains a smaller proportion of indigestible NDF. The observed rumen NDFD values were calculated from the observed rates of pdNDF digestion and passage and the measured pool of pdNDF in the rumens of cows fed the experimental diets. It is important to note that the fiber digestion parameters measured directly in the cows are independent of the in vitro measurements. Results of the study indicate that the predicted values of rumen NDFD were similar to the directly measured rumen NDFD values and provide evidence that supports the concept that in vivo fiber digestion can be predicted from in vitro fiber kinetics.

The objective of another in vivo experiment (Lopes et al., 2013b) was to compare estimates of total tract fiber digestion as predicted by the in vitro TTNDFD model to in vivo measurements in lactating dairy cows. Cows were fed diets that varied in proportions of corn silage and alfalfa. The in vitro fiber digestion parameters for corn silage (NDF = 34.4%, NDF kd = 3.2%/h, iNDF = 41.4% of NDF) and alfalfa silage (NDF = 34.7, NDF kd = 6.1 and iNDF = 48.7) indicate that fiber in the corn silage contains less indigestible NDF than alfalfa, but the rate of digestion of alfalfa fiber is faster than corn silage fiber. The feeding experiment measured how cows utilize forages that differ in iNDF and kd (Table 6). The diets contained approximately 55% forage and the dietary NDF concentration was similar across the four treatments. Feed intake was lower when cows consumed the diets that contained 100% of forage as alfalfa silage than it was when cows were fed diets containing corn silage. Milk yields were similar amongst diets. The observed (in vivo) TTNDFD values were calculated from feed and fecal samples. Cows consuming the diet with alfalfa as the only forage had higher NDF digestibility than cows on the diets that contained corn silage. Fat corrected milk yield did not differ due to treatment. The NDF digestibility coefficients predicted by the in vitro TTNDFD method were similar to the in vivo values. The fiber digestibility coefficients suggest that the faster rate of fiber digestion of alfalfa fiber compensates for its lower fiber digestibility but as higher proportions of alfalfa forage are fed, the amount of indigestible fiber in the rumen increases and rumen fill becomes a more predominant factor limiting feed intake.

Table 5. Effects of intake and source of corn silage on ruminal fiber digestion (Lopes et al., 2013).

Corn silage source	Normal		BMR		
Intake level	**Restricted**	**Ad Lib**	**Restricted**	**Ad Lib**	
Normal corn silage, % of TMR	47	47			
BMR corn silage, % of TMR			47	47	
Alfalfa silage, % of TMR	17	17	13	13	
Concentrate, % of TMR	36	36	40	40	
Diet composition					
NDF, % of diet DM	26.1	27.5	26.9	28.3	
iNDF, % of NDF	31.5	31.1	25.9	24.1	
Results					**SE**
DMI, lb/d	50.8	56.1	49.3	56.3	2.9
4% FCM, lb/d	78.1	75.5	79.0	77.0	2.4
Observed rumen NDFD, % of NDF	35.1	40.5	43.1	41.5	2.5
Predicted rumen NDFD, % of NDF	39.0[c]	38.4[c]	47.5[a]	42.8[b]	0.9

Table 6. Effect of changing ratios of corn silage to alfalfa on intake, production and fiber digestion in dairy cows (Lopes et al., 2013b).

Corn silage:alfalfa ratio	100CS 0AS	67CS 33AS	33CS 67AS	0CS 100AS	
Corn silage, % of TMR	56	37	18	0	
Alfalfa silage, % of TMR	0	19	37	55	
Concentrate mix, % of TMR	44	44	45	45	
Diet composition					
NDF, % of DM	24.9	25.5	24.6	25.5	
iNDF, % of NDF	31.1	31.6	31.8	32.3	
Results					**SE**
DMI, lb/d	55.4[ab]	55.7[a]	53.5[b]	48.1[c]	1.8
4% FCM, lb/d	79.6	77.9	77.4	78.3	1.9
Observed TTNDFD, in vivo	38.3[a]	40.9[ab]	39.4[ab]	43.8[c]	1.9
Predicted TTNDFD, in vitro	38.0	41.0	41.0	45.0	2.1

The three feeding experiments demonstrate that the TTNDFD analysis can provide important insights into fiber utilization by dairy cattle. The rates of fiber degradation determined from the in vitro NDFD assays appear to be consistent with what has been measured in vivo feeding studies. The kd, kp and iNDF parameters predicted by the TTNDFD model appear to be consistent with in vivo measures.

Summary: Using TTNDFD Values in the Field

The key to getting the most out of forages is understanding how energy values are affected by NDF and NDF digestibility. The TTNDFD test is intended to be a tool to more accurately evaluate forage fiber digestibility. In top shelf forages, NDF accounts for 35-45% of the total dry matter and this fiber is the source of 30 to 40% of the digestible energy. A 30% NDF diet with a TTNDFD of 33% would support 7 lbs less milk than a 30% NDF diet with a TTNDFD of 45% assuming no reduction in feed intake.

The TTNDFD value can be used as a stand-alone value to index forages. As discussed earlier, table 2 summarizes the typical TTNDFD values for forages submitted to a commercial lab for routine testing. A consultant could compare values from their forage test to these values. For example, note in the table that an average corn silage will have a TTNDFD value of 42%. A corn silage sample with a TTNDFD value one standard deviation below average (less than 36%), would be among the bottom 15% of the corn silages tested. A corn silage sample with low TTNDFD likely will not be utilized as well as 'typical' corn silage. Experiences in the field indicate that cows fed low TTNDFD forages produce less milk and have lower feed intake than cows fed diets with that contain forages with more digestible fiber. Likewise, a corn silage with a TTNDFD value greater than 48% is in the top 15% of the corn silage population tested and would be expected to feed better than a 'typical' corn silage. The ability to predict fiber digestibility and incorporate this information into rations could improve our ability to optimize forage utilization and milk production.

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