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Carbohydrate nutrition for lactating dairy cattle

Virginia Ishler and Gabriella Varga

DAIRY & ANIMAL SCIENCE

Department of Dairy and Animal Science
The Pennsylvania State University
324 Henning Building
University Park, PA 16802
(814) 865-5491 • FAX (814) 865-7442
www.das.psu.edu/teamdairy/

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INTRODUCTION

Carbohydrates (CHO) are the major source of energy for rumen microorganisms and the single largest component (60-70%) of a dairy cow's diet. They represent the major component of net energy for support of maintenance and milk production. Carbohydrate nutrition influences the composition of milk as precursors for lactose, fat and protein.

There are two broad classifications of CHO: structural and nonstructural. The structural CHO consist of elements found in the plant cell wall. The nonstructural CHO are located inside the cells of plants and are usually more digestible than the structural CHO. Defining the cow's requirement for CHO requires knowledge of many interacting nutrients within the diet as well as feed allocation, processing and presentation.

In order for high producing dairy cattle to meet their high-energy demands, feeding diets containing amounts of concentrates and high quality forages are necessary, usually at the expense of fiber intake. However, adequate levels of fiber are required to maintain normal rumen function and milk fat percentage.

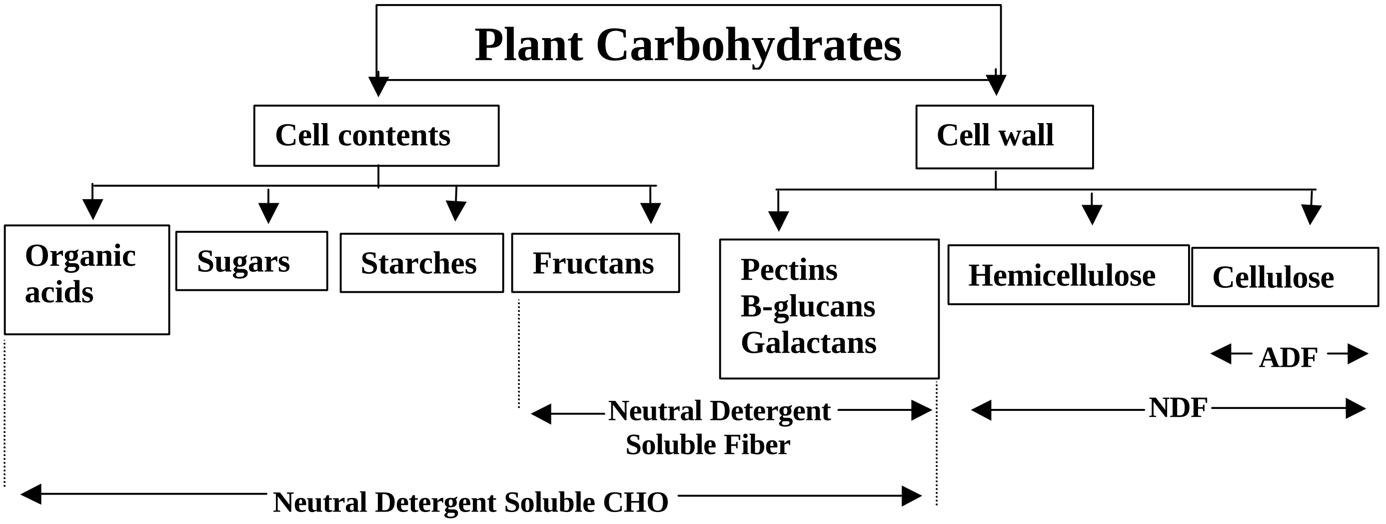
Achieving an optimum balance between structural and nonstructural CHO in dairy cattle rations is a challenge faced by nutritionists. This fact sheet will examine the limitations of laboratory analysis methods for predicting forage quality, what the different components are that make up CHO and the effect farm management practices have on CHO nutrition.

PLANT CARBOHYDRATES

Figure 1 illustrates the composition of plant CHO. The structural or cell wall material contains cellulose, hemicellulose, lignin, pectic substances and β-glucans. The cell contents contain starches, sugars, and fructans and for ensiled feeds, organic acids.

The most common measures of fiber analysis are acid detergent fiber (ADF) and neutral detergent fiber (NDF). The structural components in the plant like cellulose, hemicellulose and lignin are measured by NDF. Acid detergent fiber measures lignin and cellulose. Even though pectins are a part of the cell wall, they are considered a nonstructural CHO because compared to hemicellulose, the rumen microorganisms completely and rapidly ferment the pectin. Table 1 lists the partition of fiber fractions for various forages. Table 2 lists the nonstructural CHO of several feeds.

Figure 1. Structural and nonstructural carbohydrates of plants.



Analytical procedures for NDF

Wet chemistry analysis for ADF and NDF are based on the differential solubility of plant components. The NDF concentration of a feed is measured by refluxing the sample in a buffered solution (pH 7) that contains detergent. Water and detergent soluble compounds are removed. Included in this residue are sugars, lipids, some ash, non-protein nitrogen and some protein. However, variable amounts of ash and protein can remain with the NDF. Ash contamination can contribute up to four percentage units to the NDF value. Ideally, both ADF and NDF should be expressed on an ash-free basis. Soil is often the culprit in mineral contamination.

There have been several modifications to the analytical procedure for NDF. The first was the inclusion of heat-stable amylase in the procedure to remove starch. The other was the use of sodium sulfite to minimize protein contamination. Currently the reference method adopted by the National Forage Testing Association and which reflects the NDF values listed in the 2001 NRC for dairy cattle is the amylase-sulfite procedure.

There is some controversy over the use of sulfite in the standard procedure for NDF determination. Adding sulfite to the NDF solution reduces crude protein contamination but does not quantitatively remove all of it. Using sodium sulfite in the NDF procedure is discouraged if the residues are to be assayed for neutral detergent insoluble protein. Sulfite also attacks lignin and should not be used in a sequential analysis for lignin or for subsequent in vitro digestion.

Whenever samples are sent out for analysis, scrutinize both ADF and NDF values. In addition to ash and protein inflating NDF, feeds with lipid contents greater than 10% can be a problem and some kinds of samples offer filtering problems.

In vitro NDF digestibility

The in vitro NDF digestibility procedure is done in a test tube. Small amounts of dry, ground samples are incubated with ruminal fluid and buffer in a temperature-controlled system. Most labs look at NDF digestibility after the sample has been incubated in rumen fluid for 30 hours. The assumption is that this represents the NDF digested in the rumen of higher producing cows with moderately fast rumen turnover. Currently the system provides an endpoint value for in vitro digestible NDF.

As with any procedure there are several factors, which could affect results. They include the dilution of the ruminal inoculum, type of buffer used, particle size of the sample, type of mill used for grinding and type of diet the donor cow is fed.

It may be difficult to make any meaningful interpretation on one in vitro NDF digestibility value. Table 3 illustrates the variation in NDF and NDF digestibility of forages grown in the Northeast. To understand how these values influence animal performance in a particular farm situation almost requires several in vitro tests throughout the year and on a yearly basis. Digestibility of forage fiber components varies due to hybrids, maturity, temperature, moisture, fertilization, fermentation and processing methods.

One disadvantage with the in vitro procedure is using a dry, ground sample. This may decrease the difference between samples or result in higher digestibilities than unground wet samples.

Nonstructural CHO

The more readily digestible CHO are not recovered in the NDF. The nonfiber CHO (NFC) includes sugars, starches and the other reserve CHO such as galactans and pectins. The NFC for feeds is calculated by difference:

100 – (%NDF + % crude protein + % fat + % ash) <u>**or**</u>

100 –[(%NDF-NDFCP) + % crude protein + % fat + % ash)

NDFCP is the neutral detergent insoluble crude protein. The first equation is most commonly used, the second equation is preferred because it corrects for crude protein in the NDF. The nonstructural CHO or NSC is measured by enzymatic methods and includes only starch and sugars.

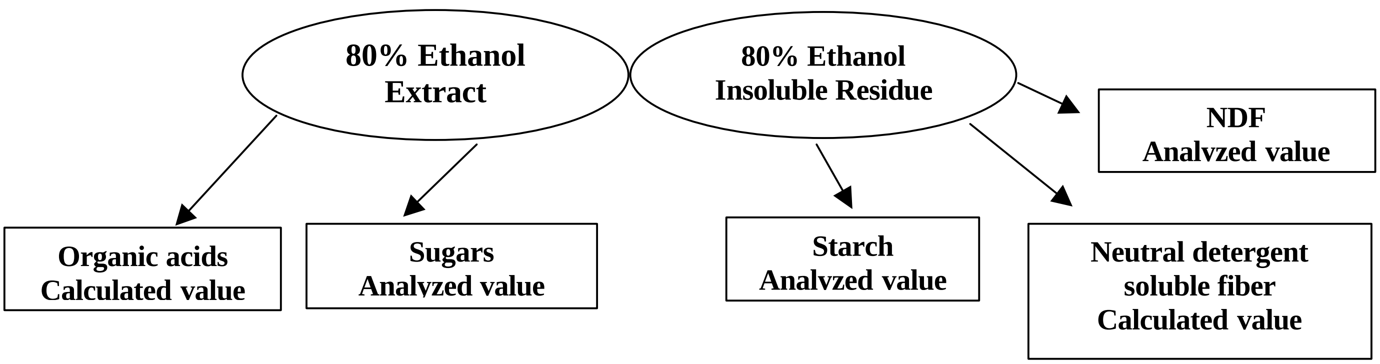
The concentrations of NFC and NSC in many feeds are not equal and the terms should not be used interchangeably (Table 4). Much of the difference is caused by the contribution of pectin and organic acids. Pectin is included in NFC but not in NSC.

PLANT CARBOHYDRATES, CONT.

When using the enzymatic method to measure NSC, sucrose and fructans appear in the starch fraction. This applies mainly to forage, particularly grasses, as they contain little if any starch. Sucrose is found in beet and citrus pulp and probably some other byproducts. For these feeds, the total sugar and starch is likely all sugar. For corn silage, grains and most byproducts, the fraction is usually all starch.

The University of Florida has developed a system for partitioning the neutral detergent soluble carbohydrates (NDSC) or the CHO fractions excluding hemicellulose and cellulose (Figure2). The system uses an extraction with 80% ethanol to separate low molecular weight sugars and organic acids from the starch and nonstarch polysaccharides. The sugars are measured directly in the ethanol extract and starch on the ethanol insoluble residue. The organic acids and nonstarch polysaccharides, which can be the most diverse fractions, are calculated by difference.

Figure 2. Partitioning neutral detergent soluble carbohydrate with 80% ethanol, direct analysis and calculated estimates.



CARBOHYDRATE DIGESTIBILITY

Fiber Digestibility

Fiber digestibility is usually defined as the proportion of consumed 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 extent of fiber digestion depends on the size of the indigestible fraction and the competition between the rates of degradation and passage out of the rumen.

Ruminal fiber digestibility is affected by the passage rate of particulate matter out of the rumen. Rate of passage is affected primarily by intake. However, feed particle size, particle buoyancy, concentrations of dietary fiber and NFC, and rate of digestion of the potentially digestible fiber fraction may affect passage rate.

There is a vast range in ruminal fiber digestibility between and among forage and non-forage sources (13% to 78%). Although fiber digestibility of forages is not constant for all animals and feeding conditions, much of the variation is due to composition and structural differences of the forage, harvest date and height at harvest. The indigestible fraction of NDF is a major factor affecting the utilization of fiber CHO sources as it varies greatly and may exceed more than one half of the total NDF in the rumen.

Table 5 illustrates that as forage mature, the indigestible fraction of fiber increases and the rate of digestion of the potentially fermentable fraction decreases. As a result, fiber digestibility generally decreases as forages mature within a cutting. In addition, environmental factors such as light intensity, day length, temperature and soil moisture affect the relationship between fiber digestibility and maturity.

CARBOHYDRATE DIGESTIBILITY, CONT.

Particle buoyancy in the rumen may be another factor affecting digestibility. Particles are buoyant when they are actively fermenting. Carbon dioxide and methane gas produced during fermentation and associated with feed particles, make them float in the rumen. Buoyant particles become suspended in the fiber mat. As the fermentable fiber fraction of feed particles decreases, less gas is produced and particles may become less buoyant and sink. Particles that have low concentrations of fermentable fiber that ferment quickly, such as alfalfa, might pass more quickly than particles that have more fermentable fiber, which ferment slowly, such as grasses.

Grasses generally have a lower indigestible NDF fraction than do legumes, which may give grass NDF higher digestibilities at longer ruminal retention times. Longer ruminal retention times of grasses due to greater buoyancy over time will tend to increase the digestibility of grass NDF, compared with legume NDF. Although grass NDF is generally more digestible than legume NDF, it may also be more filling and reduce intake because of an increased ruminal retention time. When intake is limited by ruminal fill of undigested feeds, legumes may allow higher intake than grasses as legume NDF ferments faster and probably sinks and passes from the rumen faster than grass NDF.

A practical feeding strategy can be applied from this information. Assuming a rumen retention time for NDF of 30 hours for early lactation cows and 48 hours for late lactation cows, the potential digestible NDF fraction of alfalfa may be nearly completely digested in the rumen of early lactation cows while that of grass is not. At shorter ruminal retention times, legume may have greater dry matter digestibility because of their lower NDF contents and similar NDF digestibility compared with grasses.

Grass forages may have greater NDF digestibility when fed to cows with longer ruminal retention times, such as late lactation and dry cows. Grasses may have similar or greater dry matter digestibility than legumes when offered to cows with longer ruminal retention times.

Dry matter intake in early lactation cows is usually limited by physical fill. Offering fiber sources that digest and pass from the rumen more quickly may increase energy intake. Mid to late lactation cows, because of their longer ruminal retention times, can utilize grass forages which may ferment more slowly, but have a higher potential digestibility.

NSC Digestibility

Starch and sugar make up the NSC component. Soluble sugars ferment very quickly in the rumen. When sugars are contained within plant cell walls, they are retained in the rumen a sufficient length of time to be extensively fermented.

Starch digestibility has the largest impact on the rumen and the dairy cow. Starch comprises the majority of the NSC in many feedstuffs. The rate and extent of starch digestibility is influenced by several factors.

Rate of starch fermentation varies by type of grain and processing. Starch degradability can be ranked from fastest to slowest: oats> wheat> barley> corn> milo. Processing methods such as fine grinding, steam flaking, and ensiling can alter ruminal availability of starch. In a Penn State study, it was demonstrated that effective degradability of starch in situ for cracked corn, fine ground corn and steam flaked corn was 44%, 65%, and 75% respectively. Most grain processing methods increase both rate and extent of starch fermentation and ruminal digestibility. Decreasing the particle size of a starch source, i.e. ground corn, increases both rate of digestion and rate of passage. These can have counteractive effects on ruminal digestion.

Animal characteristics and level of intake affect rate of passage. Fine grinding may have less effect on ruminal starch digestibility at higher levels of intake, such as early lactation cows, compared to animals in late lactation.

In reviewing research studies evaluating the effects of NSC in diets on animal performance, there is some variation in results. Some of the differences in results may be attributed to:

1. Effects of rapidly degradable starch on ruminal fiber digestion, which can decrease the differences between diets relative to total CHO digestion.
2. Level to which NSC or NFC replaces fiber in the diet, as this can effect rumination and saliva production.
3. Site of starch digestion.
4. Level of dry matter intake and physiological state of the animal.
5. Processing methods used to alter rate and extent of NSC or NFC digestion.

FORMULATING RATIONS FOR CARBOHYDRATES

Numerous factors influence the amount of forage NDF and total NDF that is formulated in rations. CHO nutrition requires more than meeting a certain NDF or NFC value. Other considerations include starch source, processing methods, particle size, physical and effective fiber, buffer inclusion levels, and feeding management practices. Table 6 lists suggested guidelines on NDF and NFC concentrations for lactating cow diets.

NFC/NSC Recommendations

The optimal concentration of NFC/NSC in dairy cattle diets is not well defined. When balancing rations for NSC (starch and sugar), an acceptable range in lactating diets would be 30 to 40% on a dry matter basis. If NFC (includes pectins and organic acids) is used, then a range of 33 to 42% on a dry matter basis could be tolerated.

Several factors have to be considered when determining the NSC/NFC level to use. These include the following: forage particle size, frequency of grain feeding, site of starch digestion, fiber digestibility, use of by-product feeds, dry matter intake, and grain processing method. Some feeding scenarios where different NFC levels may be appropriate are presented in Figure 3.

NDF Recommendations

Formulating rations with an “ideal” forage NDF or total NDF level is challenging. The 2001 NRC recommendations (Table 6) are minimums and they do not account for certain nutrition, management and environment issues that can have a tremendous impact on animal performance. Also, the minimum NDF required must be considered in relation to the NFC concentration (Figure 4). The minimum level of NDF should be increased so that the maximum recommended amount of NFC is not exceeded.

The maximum amount of dietary NDF that can be formulated in diets is dependent upon fiber source, amount, physical characteristics of the forage and the physiological state of the cow. The upper limit of NDF in the ration is a function of the cow’s energy requirement, the minimum amount of NFC required to maintain normal rumen function and the potential negative affect of high NDF on feed intake.

Figure 3. NFC levels for various ration types.

33-36%	➔	Barley, oats, high moisture grain, steam flaked grain, finely ground grain predominate the concentrate portion of the diet.
37-39%	➔	High quality haycrop forages predominate the ration; corn silage rations include nonforage fiber sources.
40-42%	➔	Coarsely processed corn is used; diet has a high inclusion level of nonforage fiber sources.

Figure 4. An example ration illustrating a minimum NDF level in relation with NFC.

	Early lactation	Late lactation
NDF	25%	25%
Crude protein	19%	15%
Fat	7%	3%
Ash	8%	8%
NFC	41%	49%

Formulating rations for NDF successfully means adjusting levels on a herd-to-herd basis and not using one constant value for all programs. Some of the problems of extrapolating research data and applying it out in the field are that these studies vary in many factors, i.e. stage of lactation, fiber sources and manner of data expression. It makes it difficult to determine a true relationship between NDF and dry matter intake and milk production to make any consistent recommendations. Some other reasons for the variability in NDF requirement based on research study results include the following:

1. Digesta kinetics related to stage of lactation may impact utilization of ruminal NDF.

FORMULATING RATIONS FOR CARBOHYDRATES, CONT.

2. Fiber may be characterized differently (i.e. nonforage fiber sources vs. forage fiber sources).
3. NDF is not a uniform chemical entity.
4. NDF does not account for a large portion of variability associated with ruminal availability (NDF content vs. digestibility).

There is still much research needed to understand the carbohydrate requirements of the dairy cow. Rations improperly balanced or managed for CHO can have a profound affect on rumen health and animal performance. Not only is the chemical nature of the fiber important, but also the physical form of the fiber is just as critical.

CARBOHYDRATE DEFICIENCIES AND EXCESSES

Several indicators can be monitored that may reflect rations improperly balanced or implemented for CHO. These include milk fat percentage, rumination and cud-chewing, dry matter intakes, metabolic problems (i.e. ketosis), laminitis, rumen pH, and fecal consistency.

Excess NDF or Deficient NFC

The net energy of lactation (NE_L) requirement of the cow generally defines the maximum amount of NDF to include in a ration. The maximum NDF in the ration is also the minimum amount of NFC needed for good ruminal fermentation and to avoid negative affects on dry matter intake related to high NDF levels.

In a summary of published research studies, high diet concentrations of NDF usually did not constrain dry matter intake when diets contained adequate $NE_{L.}$ Dry matter intake was limited when cows produced in excess of 90 pounds of milk and were fed diets containing more than 32% NDF. Cows producing 45 pounds of milk had restricted dry matter intake when total NDF reached 44%. However, the maximum NDF or minimum NFC a herd can tolerate relies heavily on rate and extent of NDF digestion.

Feeding situations where NDF may be excessive and NFC deficient are when feeding overly mature forages, especially grasses, and/or total mixed rations containing excessively long particle size (i.e. >20% of the particles >0.75 inches using the Penn State Particle Size Separator). The problem that occurs is a longer retention time in the rumen, which can restrict dry matter intake. This would be of concern to early lactation and high producing cows.

Inadequate NFC may depress the energy available from propionic and lactic acid production, reduce microbial protein synthesis, and decrease fiber digestion. Feeding situations that can confound low NFC diets are corn grain coarsely processed and/or the inclusion of a lot of high-fiber byproduct feeds. These scenarios illustrate the importance of evaluating BOTH the chemical and physical properties of the ration.

Deficient NDF and Excess NFC

Ruminal and cow health is negatively affected by low NDF and high NFC rations. Indicators that respond quickly to this feeding scenario are ruminal pH, milk fat percent, and chewing activity. Long-term effects include laminitis and an increased incidence of ketosis and abomasal displacement. A general term used to describe these problems and feeding conditions is ruminal acidosis.

The objective of balancing and managing CHO nutrition is to minimize deviations of ruminal pH throughout the day. Low NDF/high NFC rations lower rumen pH by decreasing rumen motility, which reduces the rate of volatile fatty acid (VFA) absorption. This occurs because rumen mixing is reduced and the concentration of VFA near the ruminal papillae is reduced. Low rumen pH damages the papillae and causes adhesion of adjacent papillae, reducing the absorptive surface area. This results in a decrease in the rate of VFA removal.

Based on a summary of published research studies, the effect of overall dietary NDF concentration is not correlated with ruminal pH. The concentration of NDF provided by forage as a percent of dry matter has a strong positive relationship with ruminal pH. However, it appears that fiber fermentability is more critical to the amount of VFA produced than either changing forage NDF as a percent of dry matter or total NDF.

Difference in sources of NDF, forage particle size, NFC source and amount, and the interaction among those factors also have a large influence on rumen pH.

Several indirect indicators can be used to determine if rumen acidosis is occurring. Typically, more than one measure should be used to determine if rumen acidosis is really the culprit.

Milk fat percentage

There is a strong positive relationship between the fat content of milk and ruminal pH. A sudden drop in milk fat percent may indicate low ruminal pH. Some points to consider when evaluating a herd are:

1. High producing, early lactation cows are sensitive to rumen acidosis, but their milk fat percent is less sensitive to changes in ruminal pH because they are mobilizing body fat.
2. There are other nutritionally related reasons for low fat tests such as the amount and type of fat being fed.
3. Bulk tank tests are not sensitive to detecting problems early on.
4. Monthly tests are not frequent enough to be useful.

Chewing activity

Rumen acidosis decreases the frequency of rumination so observing cows for chewing activity is often used as an indicator. The variation observed among healthy cows and the poor relationship between chewing time and ruminal pH, limits the usefulness of this indicator. However, a noticeable reduction in the number of cows ruminating one to two hours after consuming a meal can be used jointly with other indicators that a rumen acidosis problem exists.

Changes in dry matter intake

Historical information on feed intakes is necessary to use this indicator effectively. Feed intake is farm specific and it is influenced by numerous factors. Therefore, to distinguish between explainable drops in feed intake and those related to rumen acidosis, routine and continuous monitoring becomes important.

Fecal consistency

Manure consistency may increase in fluidity during periods of acidosis. This occurs when an increased amount of readily fermentable starch is consumed resulting in lactic acid passing to the lower digestive tract. Also, some starch may escape the rumen and get fermented to VFA in the large intestine. When either of these scenarios occurs, osmolarity increases in the digestive tract causing an influx of water from the blood. However, there are other nutritional reasons why fecal consistency may change. The degree of change in consistency needs to be evaluated and determined if it is severe enough to be a problem.

Laminitis

Laminitis is an aseptic inflammation of the dermal layers inside the foot. There is usually some inflammation and sensitivity above the hoof and around the coronary band. A general symptom of an animal with laminitis is moving stiffly. Cows standing on toes on the edge of their stall are very typical of a stance to alleviate pain.

Rumen acidosis has been shown to be a key factor leading to laminitis. As the rumen pH decreases below 5, acid production is elevated in the rumen. This increased acidity results in a stasis of fermentation. Endotoxins can be produced and released which can trigger histamine release. Histamine causes vasoconstriction, dilation, laminar destruction, hoof deterioration and the laminitis process develops. However, histamine is a chemical naturally released as a function of stress. Environmental stress and infectious diseases can also cause histamine release.

The main problem with using laminitis as an indicator is the interval between the occurrence and the appearance of the hemorrhage, as it is related to the hoof growth rate, which is .20 inches per month. The thickness of the normal sole is about 0.40 inches. Therefore, the hemorrhage is observed about two to three months after the internal insult occurred. In chronic and subclinical cases, observing hoof health and laminitis is typically a distant historical indicator of the nutrition program. It may have little relevance to the current feeding program or recent ration changes.

TABLES

Table 1. Fiber partition in various forages.

Forage		ADF	NDF		Cellulose	Lignin
	56	34	44		27	7.4
	51-	30 38	-51	5-	23 30	-9.0
Legume silage	37		47	8.9		7.7
	30 43	-44	40-	4.1 13.6	-34	5.3-
e haylage[b]	55		48	11.5		7.8
	51 60	-42	40-	5.7 17.3	-33	4.3-
	35	39		13.4	32	
	-42	35-	45 59	-18.9	29-	5.4 8.3
MM grass haylage[b]	59		54	15.7		7.7
	52 65	-43	46-	10.8 21	-34	5.5-
	36	39		17	33	
	-45	35-	50 63	-22	29-	4.7 9.0
Grass silage		41	62		24	6.4
	21-	37 44	-68	15-	31 37	-7.8
Corn silage	33		45	19		2.8
	25 40	-30	38-	15 23	-27	2.2-

Source: Samples from Dairy One Forage Testing La
Department of Animal Science, Cornell University.
Mean one standard deviation (range indicated by darker shading represents 67% of samples received) will fall within these values.
[b]MM legume refers to

Feedstuff	Sugar		Pectin	Volatile fatty acids
			% of NFC[a]	
Alfalfa silage	0		33.0	42.5
	35.4	15.2		0
Corn silage		71.3	0	
Barley grain	9.1		9.2	0
	20.9	80.0		0
Beet pulp		1.8	64.5	
Soyhulls	18.8		62.4	0
	28.2	28.2		0

uirements of Dairy Cattle, 2001 NRC.

[a] – (NDF, % + crude protein, % + fat, % + ash, %)]

TABLES

Table 3. Variation in NDF and digestibility of Northeastern US forages using in vitro analysis.

Feed	Number of samples	Analysis	Average	Minimum	Maximum
Alfalfa silage	35	NDF, %[a]	50.6	35.88	69.71
		DNDF, %[b]	51.9	36.93	65.26
		DMD, %[c]	75.15	56.03	85.67
Corn silage	50	NDF, %	46.65	32.09	63.42
		DNDF, %	43.45	24.87	61.56
		DMD, %	73.87	61.79	85.00
Grass silage	49	NDF, %	61.35	47.61	72.55
		DNDF, %	48.21	35.10	65.72
		DMD, %	67.59	53.37	83.68

Source: Miner Institute Research Report 98-8.
[a]Neutral detergent fiber.
[b]Digestibility of NDF.
[c]Dry matter digestibility.

Table 4. Nonstructural (NSC) and nonfiber (NFC) analyses of selected feedstuffs.

Feedstuff	NDF	NFC[a]	NSC[b]
	% of dry matter		
Alfalfa silage	51.4	18.4	7.5
Alfalfa hay	43.1	22.0	12.5
Mixed mainly grass hay	60.9	16.6	13.6
Corn silage	44.2	41.0	34.7
Ground corn	13.1	67.5	68.7
Beet pulp	47.3	36.2	19.5
Whole cottonseed	48.3	10.0	6.4
High moisture shelled corn	13.5	71.8	70.6
Barley grain	23.2	60.7	62.0
Corn gluten meal	7.0	17.3	12.0
Soyhulls	66.6	14.1	5.3
48% soybean meal	9.6	34.4	17.2

Source: Nutrient Requirements of Dairy Cattle, 2001 NRC.
Note: Adapted from Miller and Hoover, 1998.
[a]NFC is calculated by difference [100 – (NDF, % + crude protein, % + fat, % + ash, %)]
[b]NSC=nonstructural carbohydrates determined using an enzymatic method.

TABLES

Table 5. Digestion kinetic characteristics of legume and grass forages cut on the same date.

Hay	prebud	Stage of	NDF	Indigestible NDF	Digestible	rate, h [1]
					%	
	0	prebud		14.9	20.9	
		bud	40.0		22.6	0.098
	14		43.7	19.8		0.093
	28	full bloom		24.4	25.1	
	0	late vegetative			48.4	0.095
	7		62.2	10.7		0.087
	14	early bloom		13.9	51.5	
		full bloom	68.0		46.0	0.066

Source: Adapted from Mertens, D. R. 1988. Balancing carbohydrates in dairy rations. Page 150 in Proc. Large Dairy Herd Management Conf., Syracuse, NY. Cornell Univ., Ithaca, NY.

lines for forage NDF, total NDF and NFC for lactating cow diets.

1. Assume a Holstein cow with an average bodyweight of 1350 pounds.

	Forage NDF	Total NDF	
		% dry matter	
Cows producing > 80 pounds of milk. s.	-21	28-	37 42
Cows producing between 60- Actual dry matter intake between 44 and 49 pounds.	23-	33 37	-38
Cows producing < 60 pounds of milk. Actual dry matter intake < 43 pounds.	-33	38-	33 36

Assume a Holstein cow wi

	Forage NDF		NFC
		% dry matter	
Actual dry matter intake > 50 pounds.	15-	28 33	-40
Cows producing between 60 79 pounds of milk. 44 and 49 pounds.	-25	31-	34 37
Cows producing < 60 pounds of milk.	26 31	-40	33-

Source: Adapted from Nutrient Requirements of Dairy Cattle, 2001 NRC and field experience.

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