# Making or Breaking Rations with Forage Digestibility / Quality

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## Take Home Messages

- Forage provides the essential base for building diets for healthy, efficient, and productive herds.
- Forage quality is determined by the composition, digestibility, particle size, and other characteristics that affect how a forage functions in a ration.
- Forage digestibility affects nutrient supply to the animal and can limit intake through effects on rumen fill.
- Calling forage “high” or “low” quality is misleading for describing its value. What we want is “right” quality forages that fit the feeding situation to meet the animal’s needs.

## Introduction

Cows were designed to use forages. Forage is the base that dairy rations need to build on to have productive, healthy, efficient, profitable performance in a herd. It’s not overstating the matter to say that forage quality makes or breaks rations – the composition, digestibility, and physical form of the forage set limits on how well cows have potential to perform. It dictates how much forage you can include, and how much of other feedstuffs need to be supplemented. But, “quality” is not something that exists by itself; it has to be judged in the context of the ration in which it is included and how well it supports animal performance. In this discussion, our focus is on the role forages play in rations, how we measure and consider digestibility, and how the various aspects of quality come together to affect how we need to work with forages in dairy rations.

## What Forages Do In a Ration

The key things forages do in a ration are:

- Supply carbohydrates, protein, and minerals that can be fermented or digested to provide nutrients to the cow. This is where digestibility of the different fractions matters: digestion represents conversion of something we measure in feeds into nutrients the cow can use.
- Serve as the main source of larger, more slowly digested particles (physically effective fibre) that are essential to maintaining cud chewing and healthy rumen function. The rate of digestion of the fibre can affect how “effective” it is.
- Limit intake as the large, slowly digested particles affect rumen fill. This is where digestibility and particle size meet. A balance needs to be struck between the two to maintain rumen function and maintain good feed efficiency, but not limit intake to the point of limiting cow performance.

## Forage Sampling

To know the qualities of forages, we need analyses from good, representative samples. Hays need to be cored with enough bales sampled to represent the variation. For silages, safely taking samples during ensiling is one of the best ways to get an accurate idea of forage composition at that harvest. However, samples of the fermented feed are needed to tell you what happened during fermentation (starch digestibility, protein quality, etc.). For silages, take a subsample from silage that’s been removed for the day’s feeding. It’s safer to do that, and you’ll have a more representative sample. With grab samples from the face of a silo, you risk life and limb and you don’t get the same material (with just as much spoilage) as is fed to the cows. Foragebeef.ca has a guide on forage sampling – follow their directions, except for sampling silo faces (http://www1.foragebeef.ca/$foragebeef/frgebeef.nsf/all/ccf9).

## Measuring and Interpreting Digestibility

### Fibre

Fibre digestibility gives a way to estimate the potential for fibre to be converted to nutrients the cow can use. The value we use, Neutral Detergent Fibre (NDF) Digestibility (NDFD), is determined by fermenting a ground feed sample with rumen microbes in the laboratory, and measuring how much NDF remains after a certain number of hours of fermentation. The curves in Figure 1 show patterns of how feed NDF disappears over the course of a fermentation. Initially, there’s a lag time where not much fermentation occurs, then the microbes go into full swing, fermenting the NDF more rapidly, until they reach the limit of what they can ferment, and we reach the maximum extent of fermentation. There is debate about what time point to use for NDFD: 24, 30, or 48 hours. The 24 and 30 hour time points are early enough that differences in how rapidly the fibre is digesting may be detected. As Figure 1 shows, changes in lag time or rate of fermentation translate into differences in NDFD between samples in the earlier hours of fermentation, no matter what their final extent. The Dairy NRC (2001) lists 48 hour NDFD as the time point to use for estimating energy derived from NDF. By 48 hours, you can detect which forage has a relatively greater extent of digestion than another, but you can't tell the route – lag or rate -- by which it got there. 240 hour NDFD values are being used instead of lignin to describe how much fibre is potentially digestible. Undigested NDF, the amount of NDF remaining at a given hour, is being investigated for predicting dry matter intake. More on that later.

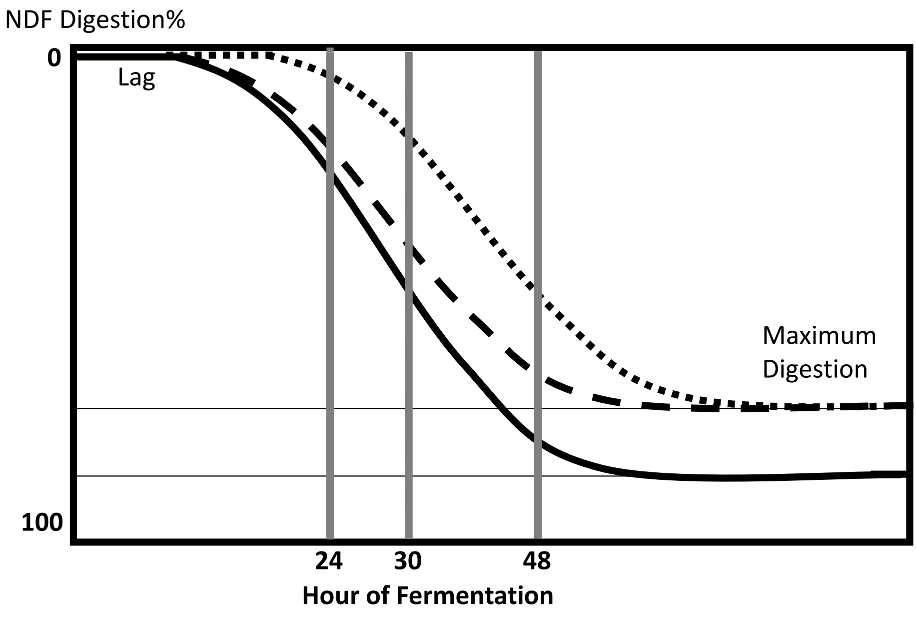


**Figure 1. Examples of patterns of NDF digestion over time. "0" = no digestion, "100" = complete digestion, Lag = time before a sample starts fermenting. The dotted curve has the longest lag, the solid curve has the greatest final NDFD. The dotted and dashed curves have the same fermentation rate, but would differ in NDFD because of differences in lag. Measures at earlier hours are more sensitive to differences in rates.**

## Interpreting Fibre Digestibility Values

Fibre digestibility is useful for comparing relative energy values of forages, but it is not a very precise number. This is not because labs are doing a bad job. All feed analysis methods have some variability, so you do not get *precisely* the same number with each and every analysis. The NDFD assay combines multiple steps that make the assay more variable than chemical analyses like crude protein. For example, commercial and research labs running 30 hour NDFD assays on 14 forage samples over multiple fermentations showed that, within a given lab, 95% of the results for a given forage sample fall between ± 4.9% NDFD from the mean (Figure 2; Hall and Mertens, 2012). Individual labs can vary somewhat from this, but the variation is similar. If a sample is run in different labs, the results fall into a range that is ± 6.6% from the mean. The labs did a good job of ranking forages in order of NDFD, but statistically, you could not separate samples that were closer than 5% NDFD apart. Take home: 1) if NDFD values are closer than 5% NDFD, they may not really be different, 2) for best consistency stick with one lab for NDFD, and 3) pay attention to how feeds rank or change relative to one another as that can reflect differences in energy content.

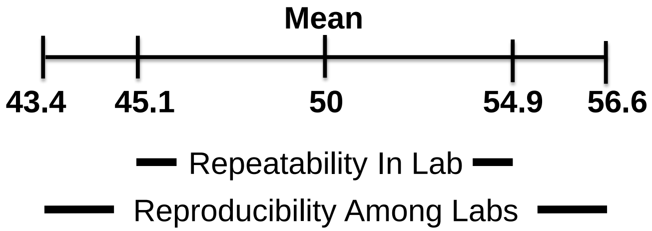


**Figure 2. The variation within and among labs in 30 hour NDFD measurements. For a given sample, 95% of the values made in 1 lab will fall within ± 4.9% NDFD of the mean; across labs values will fall within ± 6.6%. For example, in a lab, a sample with a 50% NDFD would analyze with real values ranging from 45.1 to 54.9% NDFD.**

## Nonfibre Carbohydrates

Nonfibre carbohydrates (NFC) are estimated to be 98% digestible (NRC, 2001). That may be largely true of the water-soluble carbohydrates (sugars, oligosaccharides, fructans), but not necessarily for starch. How finely ground, or fermented, or dry a feed is, or how bound the starch is in a protein matrix will affect starch digestion. Present starch digestibility assays include a 7 h in vitro fermentation of slightly more coarsely ground samples (to retain the effect of grain structure on starch degradation). Gas production measurement from in vitro fermentation of starch-containing samples does not measure only starch, but gives measures of more rapidly or slowly fermented fractions of feeds that may be aligned with the NFC (generally more rapidly fermented) and fibre (more slowly fermented). Starch degradability assays have not yet been directly linked to in vivo digestibilities, but they can give an index for how rapidly the starch is fermented for consideration in ration formulation.

## ▪ Impact of Digestibility and Forage Qualities on Cow Performance

Cows perform well on rations when the rations are digestible enough to provide needed nutrients, there is enough effective fibre to maintain rumen function and protect against ruminal acidosis, and there are some indigestible fractions that pass and carry liquid and solids from the rumen for digestion further down the tract. Within this frame, we also need to provide forage within the limitations set by physical fill (undigested bulk that takes up space in the rumen) to avoid unduly limiting intake but providing enough fibre to maintain rumen function and animal health. The 2001 Dairy NRC attempted to address all this with recommendations for NDF, forage NDF, and nonfibre carbohydrates (Table 1). However, the amount of forage or fibre needed to maintain good productivity in herds also varies with the type of NFC fed (Figure 3). The relationship between starch and forage in Figure 3 echoes the recommendations for NFC and NDF feeding offered by the 2001 Dairy NRC (Table 1): as NDF from forage increases, more starch can be safely included in the ration. If conditions are such that animals consume large meals of grain, sort their feed for grain, slug feed, suffer from heat stress, consume starch sources with very rapid rates of fermentation (high moisture shell corn, finely ground barley or wheat), it might be a good idea to include more NDF and less NFC as a matter of “risk management” to prevent digestive problems.

**Table 1. 2001 Dairy NRC recommendations for NDF and NFC formulation.**

| Minimum NDF from Forage, % | Minimum NDF in Ration, % | Maximum NFC in Ration, % | Minimum ADF in Ration, % |
|---|---|---|---|
| 19 | 25 | 44 | 17 |
| 18 | 27 | 42 | 18 |
| 17 | 29 | 40 | 19 |
| 16 | 31 | 38 | 20 |
| 15 | 33 | 36 | 21 |

NDF = neutral detergent fibre, NFC = nonfibre carbohydrates

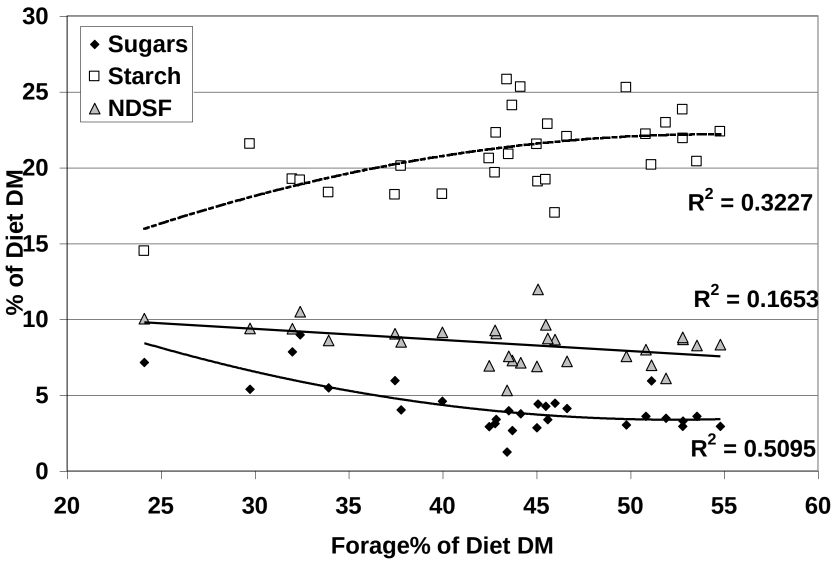


**Figure 3. Sugars, starch, and soluble fibre (NDSF) relative to dietary forage as % of diet dry matter (Hall and Van Horn, 2001). NFC was estimated from individual feed analyses. Ration data from 29 herds.**

Differences in digestibility of NDF and type or source of physical form are not taken into account by the NRC 2001. The recommended amount of forage NDF is a proxy for making sure that cows get sufficient physically effective fibre to maintain rumen function and rumination. However, fibre digestibility can affect the amount of effective fibre actually needed. If fibre is fermented rapidly and extensively, or is fragile, it will reduce in size more quickly, and pass from the rumen. If it's no longer present in the rumen, it can't help rumination. Conversely, if forage fibre is very slowly fermented, it can stay in the rumen longer to enhance rumination (think: "chopped straw"). On top of this, the physical form of the fibre (chopped corn silage vs. alfalfa silage vs. grass forage vs. wheat straw) alters how effective fibre is at increasing rumination (straw and grass more than alfalfa and corn silage).

The more slowly fermenting, bulky material can have another impact – limiting intake through rumen fill. This is the other side of fibre digestibility: undigested fibre can fill the rumen and reduce dry matter intake. Work is underway now to evaluate how well intake can be predicted based on undigested NDF (UNDF) measured at 30 (Jones and Siciliano-Jones, 2014) and 240 (Cotanch et al., 2014) hours of fermentation. There is agreement that even with UNDF, the fineness of chop of the forage as well as its fragility (like with the BMR mentioned below) will affect how UNDF relates to intake – finer material will likely pass more quickly and have less impact on fill. However, in general, feeding too much of a slowly fermented forage fibre source with a low extent of digestion will limit intake.

So, how does this translate into getting cows enough effective fibre to keep their rumens working well and maintain desired intakes? A forage fibre that ferments very rapidly and extensively may have a shorter residence time in the rumen and not induce as much rumination, so you will need to feed more of it to provide enough effective fibre to support rumen function, or supplement an adequately sized, slowly fermenting fibre. If you feed forage fibre that ferments more slowly and less extensively (think “straw”), there could be issues with the fibre filling the rumen and reducing intake, and you would need to feed less to meet effective fibre needs. Presently, there is no absolute way to know in advance whether the combinations of forage NDF, particle size, and digestibility will allow for excessive, adequate, or insufficient effective fibre. You still will need to go look at the cows. The cows are the sole authority for accurately measuring effective fibre in the diet. Sufficient effective fibre will have at least 50% of the cows ruminating if they are not sleeping, eating, drinking, or in heat. Only ~5% of the cows may have manure that does not look normal and like the rest of the herd’s (assuming no disease issues and no sorting of feed), and typically there will be limited amounts of loose manure, or long fibre (>2 cm long) in the manure.

A feed that may demonstrate the effect of various qualities on how fibre functions in the rumen is brown midrib corn silage (BMR). In the lab, BMR generally has a higher NDFD than conventional corn silage. However, feeding BMR did not increase fibre digestibility in the animal to the degree that in vitro NDFD measurements suggested it could (Oba and Allen, 1999), but dry matter intake and passage of NDF from the rumen were increased (Oba and Allen, 2000). An explanation for these results is that the BMR corn silage fermented, fragmented, and passed more rapidly from the rumen before it was completely fermented, reducing the rumen fill so cows could eat more.

Starch degradability in ensiled corn increases the longer that it is ensiled if it has adequate moisture (Hoffman et al., 2011). So, starch degradability analyses of corn silage should be performed over time to monitor the change. The challenge this presents to formulation is that starch digestibility in silage or high moisture corn is a moving target over time. By the time corn silage made at the appropriate moisture content (32 to 35%, R. E. Muck, USDA-ARS, personal communication) has been in the silo an entire winter, the fermentability of the starch may have increased appreciably. It may be necessary to limit inclusion of the more rapidly fermentable starch to avoid digestive upset. This can be problematic if corn silage is high in starch (>30% of dry matter) and corn silage accounts for most of the forage in a ration.

So, what worked for a real herd of cows? In a Wisconsin herd that averaged 43 kg of milk, 3.9% butter fat, and 3.2% protein, it was a ration that was (on a dry matter basis) 52% forage (28% corn silage, 24% alfalfa silage), and contained 27% ration NDF, 21% forage NDF, 28% starch, and 44% NFC. The 30 hour NDFD was 48% for the total diet, and averaged 45% for the forage, and 55% for nonforage NDF. Forage NDF was 78% of total NDF, and at a dry matter intake of 27.5 kg, was 0.9% of cow bodyweight (670 kg). The ration was roughly in line with the NRC recommendations. It illustrates things that can be considered for formulating for forage NDF amount and digestibility: 1) forage NDF should typically make up ~75% of total NDF or 0.8 to 1% of body weight; 2) if aiming for a total dietary NDFD to provide nutrients, you will need to balance between the digestibility of the forage, how much forage NDF you can feed without limiting intake, and how much non-forage NDF to supplement to provide digestible NDF and keep starch intake within acceptable bounds, and 3) changes in digestibility will change the values that will give the desired performance.

## ▪ Making or Breaking Rations With the Forage You Have

We talk about feeding high quality forage, but “right” quality is what we need to focus on. Right quality describes the forage that can be fed in adequate quantities to meet animal nutrient and effective fibre requirements without tempting people to break ration formulation guidelines. Forages too high or low in NDFD can both be challenges. When NDF increases, fibre digestibility typically decreases. There are usually limits on the amount of such forages you can feed without limiting intake and the cow not getting enough digestible nutrients. But, if there are limits on the amount of high NDF/low digestibility forage you can feed, what do you fill in the rest of the space with, and not go over 25 to 28% starch in order to avoid acidosis? This can be where fat or fermentable fibre sources such as soyhulls come in to add digestible feedstuffs while not exceeding limits on starch. Overfeeding starch needs to be avoided; starch will not necessarily give the energy the cow needs and can readily make matters worse as the herd deals with digestive upset and performance, digestibility, feed efficiency, and income suffer.

Very digestible forage fibre gives a different challenge: providing adequate amounts of effective fibre and avoiding ruminal acidosis. Forage that has very high fibre digestibility also can be low in NDF. Can you feed enough of it to meet effective fibre needs, balance the ration, and have the forage inventory you need to cover the year? If the inventory answer is “No”, this is where bringing in grass (silage or chopped hay) or a kilo of chopped wheat straw can be useful as effective fibre supplements to amend the ration; feed these in a moist ration that the cows cannot sort. In the high digestibility category we can also include corn silages that have more than 30% starch. Having seen corn silage that was nearly 40% starch, how do you formulate with it as your main forage? Carefully. If 60% of the ration is corn silage, and you limit starch to ~25% of diet dry matter from this rapidly fermenting source, the corn silage leaves room for supplementing 1% more starch. Then you need to select lower starch feedstuffs to fill the remaining 40% of the ration. And you still need to verify that the cows are getting adequate amounts of effective fibre.

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