Forages in a pasture can vary widely in both the quality of the material present and quantity (yield) of the material available. Both of these factors can have tremendous impact on the amounts of nutrients consumed (intake) by the animal. Yet both of these factors are vague and sometimes poorly understood. How do you know the nutrient content of your pasture or how much your animals will consume?

The nutrients

Quality of forages and other feedstuffs is often described by the amount of nutrients they contain. We use words such as “good” and “poor” to define forages that contain high or low levels of the various nutrients. We also hear terms such as “dairy-quality hay” or “dry-cow hay.” But whether good or poor, dairy or dry-cow quality, what do we actually mean?

Five main categories of nutrients are essential for livestock: water, protein, energy (primarily carbohydrates), lipids (fat), minerals and vitamins. Some of these, such as water or minerals, can be measured directly by laboratory methods. Others, such as protein, are measured indirectly by determining percent nitrogen (N) and then converting the percent N to percent crude protein (CP). Energy, on the other hand, is not measured at all but rather is calculated from known relationships between the cell wall (fiber) and energy content.

Water

The water content of feeds varies widely from 10 percent in air-dried feeds such as hay or grains to as much as 85 to 90 percent in lush pasture. Water content is inversely related to dry matter (DM) content — as water content increases, dry matter content decreases. Water content and dry matter content always add up to 100 percent. So, if a feed has 20-percent water (moisture), it contains 80-percent dry matter (100 percent - 20-percent moisture = 80-percent dry matter).

Feedstuffs and their nutritional content can be expressed on several different bases relative to the water content. “As is” basis refers to the naturally occurring levels of moisture and dry matter. For example, a pasture may have 25-percent dry matter (the same as saying 75-percent water) or 5-percent crude protein as is. “Dry matter” basis refers to a feed that has been completely dried so that there is no moisture in it; it is 100-percent dry matter and 0-percent water. “Air-dry” basis refers to a feed that has reached equilibrium with the air and by definition contains 10-percent moisture and 90-percent dry matter.

It is important to compare nutrients in forages with different moisture contents on a common basis. As an example, consider a pasture with 25-percent dry matter and 5-percent crude protein as is compared to air-dry hay with 90-percent dry matter and 16-percent crude protein. Which has the higher crude protein? To answer that question, we must convert both the pasture and the hay to a common basis. We can convert both to dry matter basis by dividing each by its dry matter content. So, the pasture with 5-percent CP as is contains 5-percent CP + 0.25 = 20-percent CP on a dry matter basis, while the hay with 16-percent CP air dry contains 16-percent CP + 0.90 = 17.78-percent CP on a dry matter basis. Thus, the pasture actually has more crude protein than the hay when compared on an equivalent basis.

Moisture content and dry matter content are most often measured by the difference in weight of a sample before and after drying. This can be done with a Koster tester, a warm (220-degree F) oven or a microwave oven (see MU publication G 3151, Using a Microwave Oven to Determine Moisture in Forages).

As an example, a sample weighing 54 grams (1.90 oz) is dried to a final weight of 20 grams (0.70 oz). To determine the dry matter content: 20 grams ÷ 54 grams = 0.37 or 37-percent DM (0.70 oz ÷ 1.90 oz = 0.37 or 37-percent DM). Moisture content is then 100 percent - 37 percent = 63-percent moisture. Remember to subtract the weight when empty of the container used to hold the sample from both wet and dry weights before performing the calculations.
Crude protein

Proteins are made of amino acids and are composed of (by weight) about 16-percent nitrogen. The standard way to estimate the protein content of a feed-stuff is to measure the nitrogen (N) content and divide by 16 percent (or multiply nitrogen content by 6.25). The resulting value is termed crude protein and contains not only true protein but also other sources of nitrogen such as urea (nonprotein nitrogen [NPN]).

Proteins are degraded in the rumen to varying extents, which results in the production of ammonia. Provided there is a readily available carbohydrate (energy) source, bacteria in the rumen then convert the ammonia back into microbial protein. Thus, the protein that passes to the intestines to be digested and absorbed is a mixture of feed protein that is not degraded and microbial protein. Some very soluble feed proteins are essentially 100 percent degraded in the rumen, and therefore none passes intact to be used by the animal. Other proteins are more resistant to breakdown by rumen microbes. Protein that escapes digestion in the rumen is called bypass protein.

Some proteins are so resistant that not only do they bypass the rumen but they are unavailable to the animal as well. This is the case for heat-damaged proteins caused by baling hay at too high a moisture content or by not packing silage adequately. The heating process that occurs causes a chemical reaction (called the Maillard reaction, “mow burn” and “tobacco browning”) that binds the protein into an undigestible form.

Protein from vegetative pastures is generally of high quality and highly digestible. Levels of 25- to 30-percent crude protein are not uncommon. However, the high digestibility means that little of the pasture protein may bypass the rumen. Research is underway to see if cattle on high-quality pastures might benefit from the addition of bypass protein to the ration.

Crude fats or lipids

Fats or lipids are important biologically. They form cell membranes, store energy and serve as solvents for hormones and fat-soluble compounds. Fats or lipids are generally of little consequence in ruminant nutrition, particularly pasture nutrition. First of all, lipids are present in small quantities (less than 5 percent) in most forages. Second, adding more than 6- to 7-percent fat to a ruminant ration can depress fiber digestion; because we want to maximize forage use in most pasture systems, adding fat may be counterproductive. An exception might be for lactating dairy cattle where whole cottonseed is sometimes used as a source of fat as well as fiber.

Minerals and vitamins

Minerals are generally categorized into the macro-minerals (calcium [Ca], phosphorus [P], sodium [Na], chlorine [Cl], magnesium [Mg], potassium [K] and sulfur [S]), which are usually found in relatively large amounts (greater than 0.1 percent) in the ration, and the micro-minerals (cobalt [Co], copper [Cu], fluorine [F], iodine [I], iron [Fe], manganese [Mn], molybdenum [Mo], selenium [Se] and zinc [Zn]), which are found in very small amounts (less than 0.1 percent or in the ppm range). Most labs will include Ca and P in their “standard” hay test, and some will also offer Mg; testing for other minerals may be available for an additional cost.

Both Ca and P are important in ruminant rations. Legumes are a good source of Ca while grasses are a good source of P. Therefore a mixed grass/legume stand can go a long way in meeting an animal’s needs for these macro-minerals. Not only is the level of each of these minerals important, but the ratio of one to the other can also be critical. Ca:P ratio should be between 1:1 to 2:1, and P should never be higher than Ca.

During spring months, Mg can be a concern because of its relationship to grass tetany. Grass tetany occurs most often in older cows in cool, wet weather on lush, early-growth pasture. If levels of Mg in the plant are insufficient to meet the needs of the animal and if not treated, the deficiency could result in hyper-excitability, convulsions, loss of equilibrium, trembling and rapid death. Supplements containing 10- to 12-percent Mg often are fed to cattle on pasture in the spring to avoid grass tetany. Levels of Mg in the forage usually are adequate at other times of the year; because Mg is not stored in the animal’s body, feeding supplements high in Mg at any time other than spring may be an unnecessary expense.

Vitamins are classified as fat soluble (vitamins A, D, E and K) or water soluble (the B vitamins and vitamin C). Most fresh forages are good sources of the fat-soluble vitamins, and the water-soluble vitamins normally are produced in adequate amounts by rumen and intestinal bacteria. One exception is vitamin B-12, which requires adequate levels of cobalt in the ration for the bacteria to synthesize it. Some vitamins may be lost during storage as hay or silage. Due to the expense of analysis, vitamin amounts are generally not determined in most feed.
Energy

Energy is not a specific nutrient but is derived from nutrients such as carbohydrates, lipids (fats) and even protein. In a pasture, carbohydrates make up the majority of the energy for ruminants. Carbohydrates often are classified into two categories: fiber (also known as structural carbohydrates) and nonfiber (or nonstructural carbohydrates). Fiber contains cellulose, hemicellulose and lignin; the first two are digested to varying extents, but lignin is 100-percent undigestible. As a plant matures, more lignin is deposited in the cell, which makes the plant less digestible. Nonstructural carbohydrates consist primarily of the soluble sugars and starches, which are readily digested and high in energy.

Structural carbohydrates are determined using the “detergent fiber” system. There are two parts to the detergent fiber system: neutral detergent fiber (NDF) and acid detergent fiber (ADF). NDF is a measurement of total cell wall, which is composed of cellulose, hemicellulose, lignin and minute amounts of insoluble ash. ADF extracts all the cell solubles plus all of the hemicellulose and leaves only the cellulose and lignin.

Why are NDF and ADF measurements important? Because they help us predict animal performance and balance rations. The two most important factors that determine animal performance are digestibility (energy) and intake. Research has shown that both of these factors can be estimated: Intake is related to the NDF content of the feed, and digestibility is related to the ADF content.

Energy can be expressed in several ways. The total energy of a feed is adjusted to account for the various losses incurred through the feces, urine and rumen gases and through assorted heat losses. The resulting term is net energy (NE), which is the portion of the total energy of the feed that is available to the animal. What's more, NE is closely correlated to the ADF content of the feed; as ADF content increases, NE content decreases.

One drawback to the NE system is that not all NE is used equally. Normally, the highest priority for the animal is to stay alive or maintain itself, and so NE of maintenance (NEm) is used with a relatively high degree of efficiency. Only after maintenance requirements have been met can the animal afford the “luxury” to grow. Because priority for growth comes after maintenance, NE of growth (NEG) is used with a lower efficiency. Balancing rations or predicting rates of gain then becomes rather complex because the producer first must determine how much of the daily ration must go to maintenance at the NEm level of efficiency and then must use a different level of efficiency for the remaining portion of the ration that goes to growth. Computer programs can make this task much easier.

Lactation also has a high priority for survival of the species, and in fact, NE of lactation (NEL) is used with about the same efficiency as is NEm. Therefore, NEm and NEL needs can be grouped into a single term for lactating cows, which simplifies ration balancing. NEm and NEL often are used interchangeably.

One important thing to remember is that regardless of what method is used to predict energy in a feed, these values are calculated from ADF values, not measured directly. Hence, the importance of ADF in ruminant nutrition.

Relative feed value (RFV)

Because animal performance is related to both intake and digestibility, measuring the NDF and ADF together is a good way to rate the potential value of a forage. Relative feed value (RFV) uses alfalfa as a standard to measure the feed value of all forages. By definition, mature (full-bloom) alfalfa hay has 41-percent ADF, 53-percent NDF and an RFV of 100 percent. Any forage with an RFV greater than 100 percent is better than mature alfalfa while feeds testing less than 100-percent RFV are of poorer quality than mature alfalfa. This becomes useful when comparing lots of hay. For example, say you are considering two lots of hay, both at a similar price and both testing at 20-percent CP. Lot 1 has an RFV of 150 percent while lot 2 has an RFV of 160 percent. Lot 2 would be expected to give better animal performance because animals would both consume more and digest more of what they consume.

One important point to remember when dealing with RFV is that it should only be used to compare forages within the same class (legumes, grasses, warm-season grasses, etc.). Avoid comparing grasses across categories, especially if one of them is a warm-season grass. At any given stage of maturity, warm-season grasses will have higher NDF (and thus lower dry matter intake [DMI]) than cool-season forages. This will result in a lower RFV for the warm-season grass even though digestibility may be similar.

Forage intake

A popular real estate saying states: “The three most important things in real estate are location, location and location.” In pasture-based livestock
operations, you could say: “The three most important things in livestock performance are intake, intake and intake.” In fact, studies show that intake accounts for at least 75 percent of the differences observed in animal performance on different forages; digestibility or quality accounts for less than 25 percent. This does not mean that quality is not important; digestibility can affect how much an animal is able to consume. But to get maximum production, we must have high levels of intake.

Grazing behavior
To understand forage intake, we must look at grazing behavior. We can determine dry matter intake (DMI) from three basic components: grazing time, bite rate and bite size. Expressed as an equation:

\[
DMI = \text{bite rate (bites/minute)} \times \text{grazing time (hours)} \times \text{bite size (lb/bite)}
\]

Increasing any one factor will increase intake. Similarly, reducing any one factor will lower intake. However, there are limits to how much each of these factors can be changed or manipulated.

Watch a ruminant in the process of grazing, and you will find that, on average, the animal will take approximately 50 bites per minute. Under certain conditions, animals can increase their bite rates, but they can only increase them for short periods of time before fatigue sets in — try chewing gum twice as fast as you normally do. Therefore, although cattle can compensate somewhat by biting faster, relying on an increase in bite rate is not a viable strategy for increasing overall dry matter intake.

Grazing time is the amount of time that an animal spends actually harvesting forage. Research has shown that cattle will spend up to 10 hours a day grazing. It would seem logical that if we could get cattle to graze longer, they would consume more. However, ruminants also must spend up to 10 hours a day ruminating (cud chewing); this is time that they are chewing but not actually harvesting forage. The combined grazing activity and rumination involves approximately 40,000 to 45,000 bites per day. Expecting cattle to spend more time and take more bites than this will again result in fatigue, and when you add on other nonchewing activities such as sleeping, you quickly run out of hours in a day. Thus, increasing the grazing time is not a viable strategy for increasing dry matter intake.

This leaves the third factor, bite size, as the only factor that we can control and manage to some extent. Research has shown that the average-sized bite contains about 0.3 grams of dry matter. The range, however, can be less than 0.1 grams to as much as 0.6 grams per bite. The single most important factor affecting bite size, and thus intake, is the availability of the forage. If pastures are short, bite size will be low, which results in reduced dry matter intake. Also, if pastures are overgrown and rank, cattle may have difficulty manipulating the forage and bite size also may be low. Optimum bite size is generally achieved when forage is approximately 8 to 10 inches tall.

Forage availability
The importance of forage availability is demonstrated in Figure 4.1. Dry matter intake increases as the available forage increases, up to about 2,000 lb DM/acre. At this point, the animal has reached maximum intake. Increasing available forage beyond 2,000 lb DM/acre does not result in further increase in intake. How much forage is 2,000 lb DM/acre? If we estimate forage yield using plant height, a good stand of tall fescue plus legume has an average yield of 250 lb DM/inch of height. So, 2,000 lb DM/acre ÷ 250 lb DM/inch = 8 inches of forage height. Because this is the height at which bite size becomes optimum, it makes sense that dry matter intake is also maximized at this forage height.

Forage quality
We stated before that forage quality affects intake. Because the rumen of an animal has a finite size, it is only capable of holding a finite amount of dry matter. Dry matter leaves the rumen by two methods: 1) digestion, the process by which feeds are broken down into soluble components that are absorbed through the rumen wall, and 2) passage from the rumen to the lower digestive tract where it is eventually excreted by the animal. Once an animal has eaten its fill, no additional feed can be consumed until this feed leaves the rumen.

With the exception of fiber, most nutrients are rapidly digested and cleared from the rumen. However, fiber is digested at varying rates and to varying extents. Immature, vegetative forages that are low in lignin are digested more rapidly and completely than more mature forages. Therefore, fiber (or more specifically undigestible fiber) plays a large role in rumen fill and thus intake.
Matching forage intake to forage availability is one of the keys to pasture-based livestock production. To estimate forage intake, we must know something about what the animal requires. Animals require certain amounts of protein, energy, fats, minerals and vitamins. Together they make up the total dry matter needed by the animal. In the United States, dry matter intake is commonly expressed as a percentage of body weight (BW). Our goal is to try to match what the animal needs with what is available in the pasture.

Keep in mind that intake estimates are just that — estimates. These estimates are not intended to be absolute and unchangeable. They are starting points from which producers make management decisions. Producers then make adjustments based on animal and pasture response.

Estimating intake as a percentage of body weight

It should be obvious that intake is related to the size of the animal. Larger animals naturally eat more than smaller animals. This basic relationship allows us to express intake, regardless of body size, on a percentage basis or lb DMI/100-lb body weight. Thus, if we assume an intake of 3 percent of body weight, an 800-lb cow would be expected to consume 800 lb x 3 percent = 24 lb of dry matter per day while a 1,400-lb cow should consume 1,400 x 3 percent = 42 lb of dry matter per day.

There are two limitations to using the above method for estimating intake. First, not all animals will voluntarily consume 3 percent of body weight. Physiological status of the animal can greatly affect intake. For example, a dry cow may only be expected to eat 2-percent BW while a high-producing cow may consume 3.5- to 4-percent BW or more. Heifers (or steers) gaining 1.5 to 1.8 lb per day would likely have intakes in the 2.5- to 3.5-percent range. Animals in low body condition may temporarily consume over their expected levels of intake when offered optimum availability of high-quality forage.

The second limitation to using the above method to estimate intake is related to forage quality. Because of the influence of quality on rumen fill, low-quality forages are consumed in lower quantities than high-quality forages. Thus, even though a lactating cow may have a high intake requirement, rumen fill may limit her ability to meet that requirement on lower-quality forages. Table 4.1 shows what levels of intake we might expect for different quality forages.

### Table 4.1. Expected Intake of lactating cows as a percent of body weight for different quality feeds.

<table>
<thead>
<tr>
<th>Forage quality</th>
<th>Relative feed value (RFV)</th>
<th>Intake as a % of body weight (BW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>&lt;100</td>
<td>1%</td>
</tr>
<tr>
<td>Average</td>
<td>100</td>
<td>2%</td>
</tr>
<tr>
<td>Good</td>
<td>120-130</td>
<td>2.5%</td>
</tr>
<tr>
<td>Excellent</td>
<td>&gt;150</td>
<td>&gt;3%</td>
</tr>
</tbody>
</table>

Estimating intake based on NDF as a percentage of body weight

Because DMI as a percentage of body weight does not address the issue of forage quality on intake, an alternative method using NDF as an indicator of quality may give more accurate intake estimates. Research has shown that, because of the rumen-fill effect, animals will consume about 1.1 to 1.2 percent of their body weight as NDF. Using this information, we can easily calculate intake if we know the animal's weight and the NDF content of the forage the animal is consuming.

For example, if a forage contains 40-percent NDF, DMI would be 0.012 + 0.40 = 0.03, or 3 percent of body weight; for a 1,200-lb cow, that works out to 36 lb of DM. That same cow, if offered a forage with 50-percent NDF, would consume 0.012 + 0.50 = 0.024, or 2.4 percent of body weight; this translates to 28.8 lb of DM. Using this method, we find that for a given size cow at a given physiological state, as forage quality declines (NDF goes up), DMI declines as expected.

To refine this method even further, some
researchers are exploring indigestible NDF rather than total NDF as an indicator of forage quality and rumen fill. Data suggest that animals will consume approximately 0.7 to 0.8 percent of their body weight as indigestible NDF. Because indigestible NDF values are not readily available at this time, this method is not widely used.

**Forage quality and quantity affects intake**

The recommendation to turn cattle into a new paddock at 8 to 10 inches of forage height and remove them when they have grazed down to a stubble height of 3 to 4 inches is not arbitrary. Rather, this recommendation is made for very specific reasons. Forages that are maintained at 8 to 10 inches are generally vegetative and high in quality. High-quality forages are needed to support high levels of intake (greater than 3-percent BW) needed for high animal productivity. Bite size also is maximized at 8 to 10 inches of forage height, thereby ensuring a high level of intake. In addition to limiting regrowth, leaving a stubble of less than 3 to 4 inches also limits animal intake. By the time animals have grazed down to 3 to 4 inches of stubble, bite size is being significantly compromised. The animal is no longer capable of attaining high rates of intake because there is not enough forage available, so animals need to be moved to a fresh paddock where more forage is available.