The ABCs of dairy nutrition

by Laurie A. Winkelman

WHEN it comes to feeding dairy cows, we first must "learn to crawl before we walk." Understanding all the terms and phrases can be a daunting task to the untrained eye. So, before we run full speed into formulating a ration, let's first explore some basic definitions associated with nutrition.

Forages are the base . . .

Rations, or diets for cows, consist of forages, concentrates, and various other feed by-products and additives. **Forages** are usually the solid base of a ration. The term forage broadly covers all leafy plant parts, including leaves, stems, and flowers. Forages are typically fed either dry, as in alfalfa or grass hay, or with moisture content, like corn or alfalfa silage. They are usually very high in fiber which promotes a healthy rumen environment.

> ***First of a 3-part series***
> ***In this issue: ABCs of dairy nutrition***
> ***Next issue: Common feedstuffs and what they do***
> ***ruary 10 issue: Bringing it all together***

Concentrates make up a large group of feedstuffs that include grains, products from grain processing, protein sources, as well as vitamin and mineral mixes. Concentrates typically provide energy, protein, vitamins, and minerals. Depending on what's in it, a typical ration may include 40 to 60 percent forage, with the rest being comprised of concentrates.

Feeds like forages and concentrates provide the cow with nutrients, so let's take a closer look at nutrients. Nutrients are defined as the most basic substances that living things need to survive.

Nutrient balance is important . . .

Cows require six essential nutrients for optimal growth, production, and body maintenance. These nutrients are water, carbohydrates, fat, protein, minerals, and vitamins.

Water is the most important nutrient that all living things need. It assists in feed digestion, moving the other nutrients throughout the body. Besides carrying the nutrients, water also dilutes and carries out waste products and is essential in regulating body temperature.

While we commonly think of water in terms of having a fresh, clean water source available for our cows, we must not forget that water is also a vital part of our feedstuffs. Every feedstuff has water in it, though some have much more than [illegible] often hear the term dry matter (DM) [illegible] discussing feeds. **Dry matter** is the amount of the feed left if all the water is removed. For instance, let's say we have corn silage that is 35 percent DM. This means that, if we have 100 pounds of corn silage, we are only feeding 35 pounds of actual DM, and the remaining 65 pounds is water.

In talking about how wet a feed is, we can either say DM basis or on an as-fed basis. Dry matter basis makes comparing nutrient content easier by eliminating the water weight. As-fed basis includes water content. Most feed nutrient values are expressed on a DM basis. This equation shows you how to convert the amount of feed from as-fed to DM basis, as long as you know the percent DM: pounds of feed (DM basis) = (Pounds of feed as-fed x % DM)/100.

So, from our corn silage example, let's feed 25 pounds of silage on an as-fed basis. How much is that on a DM basis?

(25 pounds x 35% DM)/100 = 8.75 pounds of DM

Let's move on to **carbohydrates**. Carbohydrates are made up of three elements: carbon, hydrogen, and oxygen. These three elements can be arranged in countless combinations and provide an excellent source of energy for the cow. There are two basic types of carbohydrates: structural and nonstructural (NSC).

Structural carbohydrates provide physical form for a plant, giving it rigidity. Cellulose, hemicellulose, and lignin are structural carbohydrates. Lignin cannot be digested by anyone or anything, including rumen microbes. Cellulose and hemicellulose can be broken down by the rumen microbes to provide energy for the cow.

When measuring structural carbohydrates, we broaden the term and call it fiber. Any fast-fingered dairy bowl participant can tell you that NDF and ADF stand for **neutral detergent fiber** and **acid detergent fiber**, respectively. What is less known is what these terms actually mean! Both NDF and ADF are lab analyses used to determine how much fiber is in a feed. Both measures reveal the cellulose and lignin content, while only NDF accounts for hemicellulose. Knowing the fiber and structural carbohydrate content of feeds is important in ration balancing.

On the other hand, when feeding grains, concentrates, and many by-products, **nonstructural carbohydrates** receive more attention. Nonstructural carbohydrates consist of simple sugars and starches. Unlike the structural carbohydrates that are slowly digested, NSCs move more quickly through the rumen and provide greater amounts of energy for the cow. It may be tempting to feed large quantities of NSC to meet energy needs. However, too much NSC in the diet can disrupt rumen balance and cause metabolic upset, such as acidosis. When feeding cows, we always have to remember that, for the herd to be most productive, the rumen and its microbes must be functioning at an optimal level.

Carbohydrates are not the only nutrients that add energy to rations. **Fats** are also rich in energy. Feeding fat is very common because fats provide the extra energy boost cows need to produce milk at a high level. Typical rations usually contain between 3 and 7 percent fat, as a percent of DM. Dietary fat can be fed through both natural and synthetic sources. Natural sources include cottonseed, whole soybeans and other seeds, and tallow. Additional natural fat sources include by-products such as hominy, distillers' grains, and fish meal. Synthetic sources include many different calcium salts of fatty acids, as well as saturated tallow.

As with NSC, it may seem tempting to include higher concentrations of fat in rations to increase energy intake. However, too much fat interferes with normal rumen function, resulting in lower feed intake and drops in milkfat and protein production.

Protein solves many needs . . .

Energy from carbohydrates and fat certainly help the cow produce large amounts of milk, but that's not the only part of the story. **Protein** is an essential nutrient in cow nutrition and is needed for growth, maintenance, pregnancy, and lactation. When broken down to the scientific elements, proteins contain nitrogen, carbon, hydrogen, oxygen, and sometimes sulfur. These elements bond together in hundreds of combinations to form **amino acids**. Amino acids, the building blocks of proteins, join together in countless ways to form proteins.

Protein is broken down throughout the digestive system. About 65 percent of dietary protein is broken down to ammonia in the rumen and used by the rumen microbes for growth. This protein is called **rumen degradable protein** (RDP). And as you could guess, protein undigested by the rumen is called **rumen undegradable protein** (RUP) or bypass protein. Bypass protein is mainly digested in the abomasum and small intestine. Cows and the rumen microbes need a careful balance between RDP and RUP to maximize production and minimize nitrogen excretion into the environment.

Small amounts but big impact . . .

Though included in rations in very small amounts, the functions of **vitamins and minerals** are very important in cow health and production. The macrominerals, including salt (sodium chloride), calcium, phosphorus, magnesium, potassium, and sulfur play are important for bone growth and maintenance, chemical and enzymatic reactions, muscle function, and milk production.

Microminerals, also known as trace minerals, include copper, iodine, iron, manganese, molybdenum, selenium, and zinc. Trace minerals share many of the same functions as the macrominerals, except that the microminerals are required in much smaller amounts. Deficiencies in minerals cause a number of problems. For example, in early-lactation cows, a calcium deficiency may result in milk fever and a selenium deficiency could result in retained placenta or metritis.

Vitamins are also important for normal body function and productivity. They are broken down into two classes, fat soluble and water soluble. The fat soluble vitamins include vitamins A, D, E, and K. The water soluble vitamins include vitamin C and an assorted complex of B vitamins. Biotin, one of the B vitamins, is important for hoof health. Generally, most vitamins and minerals must be added to rations to meet all of the cows' requirements.

We've finished crawling through some of the basic nutrition terms. We feed forages and concentrates to provide the six essential nutrients for optimal production and growth. You are ready to take your first steps in evaluating feedstuffs and rations! In the next article of this series, we'll examine feedstuffs, their common characteristics, and how they are used to meet a cow's nutrient requirements.

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Feeding to meet your cows' needs

A RATION needs to consist of just the right combination of feedstuffs to meet your cows' needs. Frequent feed analysis is also important to keep rations accurate.

by Laurie A. Winkelman

CARBOHYDRATES, protein, vitamins, minerals, fat, and water. Armed with basic knowledge of these six nutrients, we can now take the next step in providing those nutrients to cows through a variety of feeds. Understanding feedstuff nutrient composition becomes essential in designing rations for cows. In this article, we'll look at general characteristics and nutrient content of some commonly used feeds. Keep in mind that, in the real world, nutritionists use results from feed analysis to obtain more exact estimates of nutrient composition when they design a ration for your farm.

Besides nutrients, in the first article we also talked about the two basic types of feeds — forages and concentrates. These two classifications separate feeds not only by type but also give some hints of nutrient content as well. In general, concentrates provide the energy of the diet, while the forages provide carbohydrates and more specifically, fiber. Energy is a very important factor in a cow's diet because if there is inadequate energy intake, the cow will not perform to her potential. That's why it might be tempting to include lots of concentrates in the ration to meet the cow's energy needs. However, ration formulation is not that simple, as cows require a good mix of both energy and fiber to promote a healthy rumen. Let's learn a little bit more about each of these feed categories and some examples of different feeds.

Forage — the foundation of the diet . . .

Forage is commonly provided at 40 to 60 percent of a cow's diet. Commonly fed forages include corn silage, alfalfa silage, alfalfa hay, grass hay, oat silage, and many others. The nuts and bolts of most lactation diets are corn and alfalfa silage and alfalfa hay. Corn silage is a high energy forage. Good corn silage is about 33 percent dry matter, meaning it contains a large amount of water. While it is a good source of nonstructural carbohydrates, corn silage contains very little crude protein.

In contrast to corn silage, alfalfa silage and alfalfa hay provide a good source of protein but contain only moderate amounts of energy. Alfalfa silage is typically drier than corn silage, while alfalfa hay contains very little moisture at all. Both alfalfa silage and hay provide a moderate amount of highly digestible fiber. The alfalfa plant is enriched with macrominerals, and alfalfa forages are an excellent source of calcium. With all forages, quality varies with maturity and storage, so it is critical to have accurate feed analysis to know the actual nutrient content for ration balancing.

Grass-based forages contain high amounts of fiber and low quantities of protein. Because high-producing cows require large volumes of feed to meet energy requirements, grass forages are not commonly included in rations for milking cows because of the high fiber content and relative low energy and protein composition.

Straw is also considered a forage, at least when it is included in rations! Though rarely fed in high-yielding cow diets, straw is commonly added to far-off dry cow diets because of its very low nutrient composition. Straw is very high in fiber, promotes rumen fill, and causes feed to move more slowly through the digestive system.

Most of the forages above are used in total mixed rations or fed as parts of a component based diet. However, grazing systems also rely heavily on forages for feed but are obviously fed differently. Many different types of grasses and plants are used as a part of intensive grazing operations. The varieties chosen by the producer are carefully selected to meet the nutrient needs of the animal. Based on the estimated pasture or grass composition, the producer will then supplement the cows with a concentrate or grain mix to meet the remaining energy and nutrient requirements.

Concentrates provide energy . . .

As we learned in the first article of this series, concentrates include a wide range of feeds including grains, products from grain processing, protein sources, and vitamin and mineral mixes. Commonly fed grains include corn, wheat, oats, barley, and milo. Wheat, oats, and barley are also excellent sources of protein. Grains can be fed completely dry or with some moisture in them, like high-moisture corn. When feeding wet grains, we must always take the water content into account and adjust the amount fed accordingly. Overall, most grains are excellent sources of nonstructural carbohydrates, energy, and some protein.

Though not necessarily considered a grain, whole cottonseed is an excellent source of energy, fiber, and protein as well. This combination of nutrients is very unique among feedstuffs. Cottonseed contains a large amount of oil and is commonly fed in one of two forms, linted or delinted.

Soybean meal is commonly added to diets as a source of protein and energy. Containing about 48 percent crude protein on a dry matter basis, soybean meal is one of the most popular protein supplements fed to dairy cows.

Not to be confused with soybean meal are soybean hulls. While they both come from soybean processing, the composition and makeup of these two feedstuffs is drastically different. Soybean hulls are very high in digestible fiber and are much lower in protein than soybean meal. While hulls are high in fiber, the fiber does not stimulate rumination, so they cannot be substituted for forage when feeding for rumen health.

Most "meals" provide good sources of protein for the cow. Other meals include blood meal, fish meal, feather meal, and many oilseed meals. Blood meal, not to be confused with meat and bone meal (which is not allowed to be fed to cows), is an excellent source of crude protein and especially the amino acid lysine. Fish meal, despite its strong odor, is a good source of rumen bypass protein and is high in the amino acids lysine and methionine. Fish meal must be introduced slowly to the ration because cows do not really like the fishy odor of their feed. Feather meal is not commonly added to ruminant rations because it is relatively unpalatable. However it is a source of slowly degraded rumen protein. The other oilseed meals include cottonseed meal, linseed meal, and canola meal. It is often a good idea to mix plant meals with animal meals to provide a good mix and balance of amino acids.

By-products offer options . . .

Many of the concentrates commonly fed to cows are by-products of another industry. By-products provide producers with alternative and potentially cheaper sources of nutrients to feed their cows. We already mentioned soybean meal and soybean hulls, they are by-products of soybean milling and processing. Commonly talked about by-products include distillers' grains and beet pulp. More interesting by-products include cookie meal or leftovers from candy production. When feeding by-products, it is usually very important to analyze feed samples regularly for nutrient composition, as quality can very greatly from one source to another, and even between batches from the same supplier.

Distillers' grains are the by-products of ethanol industries. Ethanol production from corn has picked up speed in recent years in the U.S. As a result of greater demand for ethanol, millions and millions of pounds of distillers' grains are produced every year. Distillers' grains vary greatly by source and type of processing, so it is very important to obtain distillers' grains from a reliable source. Distillers' grains are high in energy and protein and can be fed either wet or dry. Phosphorus levels can be fairly high in this by-product, so it is important to balance the ration for phosphorus to minimize excretion into the environment.

> ***Second in a 3-part series***
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> ***This issue:** Feeding to meet your cows' needs*
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Though we most often think of beet pulp as feed for heifers or cows at a show, it can also be fed in lactating rations as well. Beet pulp is the leftovers from sugar beet processing. Beet pulp is high in very digestible fiber and is a good carbohydrate source. When water or moisture is added to beet pulp, the shreds swell and expand.

Besides the energy and protein concentrate sources, we must not forget about the vitamin and mineral needs of the cow. Vitamin and mineral requirements are commonly met through supplementation with premixes made by feed mills.

While we've given some most basic characteristics of different feedstuffs fed to cows, the resounding theme throughout this article is individual feed analysis. These general characteristics about forages and concentrates are just the first steps in formulating rations for cows. Nutritionists must rely of individual feed analysis estimates to better know the nutrient composition of feeds before designing the ration. Ration formulation is relatively easy with the right tools; it just takes a little teaching, time, and patience.

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YOUNG DAIRYMEN

Putting our nutrition knowledge to work

by Laurie A. Winkelman

IN THE last two articles of this series, we've developed our vocabulary of nutrition terms and explored the various types of feedstuffs that are available to feed our cows. We've come a long way in our quest of understanding nutrition, and our final adventure will be to investigate various tools we can use to evaluate our feeding programs.

Though we haven't explicitly told you "feed xx pounds of corn silage and xx pounds of roasted soybeans" and so on, that was not the intention of this series. Obviously, the quality and nutrient content of feed varies from farm to farm. Therefore, there is not one recipe in feeding cows. Remember, we feed for the cow's requirements which have been detailed in the National Research Council's book titled, "The Nutrient Requirements of Dairy Cattle," published in 2001.

> ***Third in a 3-part series***
> ***January 10 issue: ABCs of dairy nutrition***
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> ***This issue: Putting our nutrition knowledge to work***

Today's nutritionists use forage and feed analyses and computer programs to put together a ration that meets your cows' needs. However, formulating and designing rations is not as simple as "plugging the numbers in and letting the computer do the work." Ration formulation takes practice, skill, and experience to meet not only cows' nutrient needs, but your economic needs.

More than just nutrition work . . .

Nutritionists are called upon to provide advice about what to feed and how to feed it, as well as to evaluate cow physiology, behavior, and health. To be competitive in their job, they must offer more than just ration formulation in their service package. Oftentimes, a nutritionist serves as a consultant for the whole operation, all the way from cow health and disease to harvesting and storing feed. Nutrition is a tricky business. Changes in ration formulation may or may not have immediate impacts on milk production. Impacts, good or bad, on cow health and longevity will be even farther down the road. So, rather than waiting until problems arise from ration and feed changes, nutritionists use a host of tools to monitor progress and, hopefully, prevent problems.

One way to evaluate a ration is to measure the overall particle size. Particle size is very important because, if there are too many large particles, cows will sort those particles and not consume the diet designed for them. If particle size is too small, digestive upset could arise. Researchers at universities have spent a great deal of time finding the ideal distribution of ration particle size. A fairly universal tool used to evaluate ration particle size is the Penn State particle size separator.

The Penn State "shaker box" is a collection of four boxes stacked on top of each other. Three of the boxes have holes in them in order to separate the feed by size. The uppermost box has holes 0.75 inch in diameter. The middle sieve has holes about the diameter of a pencil or 0.31 inch, and the lower sieve has very small holes, with a pore size of only 0.07 inch. A nutritionist will take about 3 pints of feed, put it on the top screen of the separator, and complete a series of shaking and turning to separate the feed by size. At the end, they'll weigh the feed on each screen and the bottom pan and divide that number by the total weight to get a percentage.

Researchers tell us that the particle size breakdowns should be as follows: 2 to 8 percent of the TMR should remain on the top screen with the largest holes, 30 to 50 percent should remain on the middle sieve, 30 to 50 percent on the bottom sieve, and less than 20 percent should fall all the way through the separator to the collection pan. If the ration falls outside of those "ideals," the nutritionist will look for ways to solve the problem. This may require changing the TMR mixing times or evaluating forage or grain processing methods, either at harvest or on-farm.

A nutritionist will also use the Penn State particle separator to evaluate refusals. Ideally, what the cows won't eat should be representative of what was originally fed to her! There is some wiggle room. However, it is inevitable that the cows will sort a little as they eat throughout the day.

Manure evaluation another tool . . .

Besides evaluating the particle size of the feed that goes into the cow, a nutritionist can also evaluate what comes out of the cow, namely the manure. Barring any diseases, manure consistency can tell a lot about how the cow is using the ration. Manure is scored on a 1 to 5 scale, with 1 representing very watery, runny manure, and 5 representing very hard clumps of manure. The middle of the scale, 3, is the optimal manure consistency score. If there is too much deviation from the middle, a nutritionist may tweak the ration.

For example, if the manure becomes too loose, excess degradable protein in the ration may be the cause. Or maybe the particle size is too small, or there may be inadequate fiber or effective fiber in the ration. Another question to ask is whether or not there is consistency across a group of cows' manure. If there is large deviation in manure scores of a feeding group, this may indicate that sorting at the feed level is a problem.

If the manure is foamy with a lot of trapped air bubbles, or very loose and runny, this is a sign that the rumen is not functioning properly. Ruminal acidosis, or when the pH of the rumen is too low, may result in runny or foamy manure.

We've already learned about feed particle size separation, but there is also particle size separation for manure. Manure separators are not as straightforward as the feed separator and are more qualitative in nature. When separating manure, a nutritionist is evaluating the size of feed particles that pass out of the cow and seeing if there are large amounts of undigested material.

While nutritionists can look at the TMR and manure to evaluate ration performance, they can also look at everything in between. This includes milk production and lactation performance and physical characteristics about the cow, such as body condition score. Most well-managed dairy herds have a recordkeeping system to follow milk production and performance. Such systems include DHI or on-farm monitoring and computer programs like PCDart or DairyComp305. Whatever the recordkeeping system, a good nutritionist uses records to evaluate the ration's ability to meet the cows' and producers' needs.

Often we'll hear "my cows are milking 90 pounds a day" or similar comments from a producer. Production level is a variable that many producers use to gauge herd productivity. However, most nutritionists dive much deeper into production records than looking only at milk yield. Component levels can give the nutritionist insight to rumen health. For example, if the milkfat percentage is lower than the milk protein percentage, ruminal acidosis is likely the culprit. This is called a milkfat-protein inversion.

A PENN STATE SHAKER BOX is an important tool to evaluate a ration particle size and to monitor sorting.

Production levels at key points of the lactation cycle are also helpful in evaluating ration and nutrition performance. Peak milk production typically occurs around 60 days in milk (DIM), but DHI defines peak milk as "the highest yield recorded during the first 90 DIM. Peak milk is related to total lactation yield, so it is a measure of productivity. First-lactation heifers should have a peak milk yield of about 75 percent of mature cows. If cows aren't peaking at adequate amounts or they are peaking at much later DIM, this may indicate a problem during the transition period. The transition period is a delicate time, and even slight problems here may result in major production losses down the road.

Body condition scores tell the nutritionist if the cow is using the diet energy for milk production or for weight and condition gain. This simple system is a visual evaluation of body fat and is based on a 1 to 5 scale, with 1 being severely underconditioned and 5 being severely overconditioned. Recommendations for body condition score in various stages of lactation are in the table below.

Recommended BCS at various stages of lactation

Calving	3.0 to 3.5
Breeding	2.5
Late lactation	3.0 to 3.5
Dry period	3.0 to 3.5

These tools are just the tip of the iceberg when it comes to evaluating on-farm nutrition. A host of others are used by nutritionists and producers on a daily basis. It's not just a matter of balancing rations anymore. Today's dairy nutritionists are called upon to be much more. The nutritionist must deeply understand cow physiology to adequately diagnose ration problems and to suggest proper solutions. The most successful nutritionists use the tools discussed in this article and others to improve cow performance and the overall bottom line of the producer.

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