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Test, don't guess! Why you should analyze feeds and forage and how to use the results

Janna Block, North Dakota State University Extension Livestock Systems Specialist

Global demand for livestock products is expected to double over the next 30 years, largely due to human population growth and increasing income (Thornton, 2010). The livestock industry is under pressure to increase production while reducing emissions and use of natural resources and improving the environment. Continuing advancements in livestock breeding and genetics, animal health, and nutrition are necessary components of increasing potential production efficiency.

Feed costs may account for up to 70% of annual operating costs for a livestock operation, and feed analysis is one of the best returns on investment for managing costs (Gunn and Schwab, 2016). The best use of any feed begins with understanding nutrient content and quality of feeds, as well as the target animals' nutrient requirements. Laboratory analysis to determine quality of feedstuffs was first utilized approximately 150 years ago. Since that time, the accuracy of analysis has greatly improved, as has the ability to use results to improve livestock feed efficiency and performance. However, this valuable management tool is still underutilized.

Forages are often used as primary source of nutrients for a variety of livestock diets. The potential for a certain type of forage to produce a desired response by livestock is determined by a number of factors, including palatability, intake and digestibility, and nutrient content (Ball et al., 2001). Grouping forages by categories such as species and/or timing of harvest are common practices to help characterize types of hay to be used for livestock feed. In addition, many livestock producers use sensory evaluation of forages to estimate quality. This includes evaluating maturity, amount of leaf and stem material, texture, color, and smell. The leafy portion of the plant provides the greatest amount of digestible nutrients, and a greater leaf to stem ratio can indicate higher quality forage. Bright colored forage indicates proper cure and hay that will likely be palatable for livestock. Smell can indicate forages that have heated or that may have mold problems. However, using sensory evaluation alone as indicators of quality may be deceiving. For example, discoloration of forages may be caused by rain or sunlight. Bleaching due to sunlight is not as damaging to forage quality as rain, which can cause leaching of soluble nutrients that lowers nutritional value of the forage.

Producers who do not utilize laboratory analysis are simply using their best guess when it comes to their herd's nutrient requirements. For example, winter feeding programs for pregnant cows may be based on strategies such as estimating intake based on body weight and using poorer quality forages earlier in gestation. These nutritional management strategies may be used for years or even generations on some operations with few observed negative effects, providing little motivation to make a change. However, managing in this manner could result in nutrient imbalances (toxicities or deficiencies) that may have negative impacts on performance and reproduction (Table 1).

Determination of nutrient content of feeds through proper sampling and laboratory analysis is essential to help producers develop cost-effective and efficient nutritional management strategies. Results of laboratory analyses are critical when developing rations. Rations must be balanced to provide specific amounts of energy, protein, vitamins, and minerals on a daily basis. Nutrient content can be matched with requirements for various classes of livestock to determine the best value for given production goals. It is nearly impossible to compare various feedstuffs without this type of information. Analysis can also help producers determine if a particular feed is safe for livestock or contains excessive amounts of toxins such as nitrate, sulfur, or mycotoxins. Finally, knowing the amount of nutrients such as protein and energy provided by a certain feed can be extremely helpful when marketing feeds to potential buyers.

Table 1. Potential consequences of nutrient imbalances in beef cattle

Level of Nutrient Consumed	Consequence
Excess energy	Poor conception rates, abortion, calving difficulty, retained placenta, reduced libido, excess weight gain
Inadequate energy	Reduced calf birth weights, calving difficulty, reduced quality/quantity of colostrum, loss of body condition, delayed puberty, reduced conception rates, lowered immune function
Excess protein	Poor conception rates, increased passage rate, diarrhea, reduced milk fat percentage, loss of body condition
Inadequate protein	Decreased fermentation and digestibility, reduced feed intake, weight loss, lowered immune function, unthriftiness, calving difficulty, decreased milk production, increased calving interval, poor conception rates
Excess vitamins/minerals	Decreased animal performance, anorexia, weight loss, diarrhea, and mineral-specific disorders such as urinary calculi, grass tetany, and polioencephalomacia
Inadequate vitamins/minerals	Lowered immune function, weakness, calving difficulty, retained placenta, reduced calf survivability, poor growth, unthriftiness, decreased milk production, poor conception rates, respiratory infections

* Adapted from George et al. (2001) and Bearden and Fuquay (1992)

Accurate sampling is key to success

One of the main challenges with feed sampling and analysis is that a single, small sample is often representing hundreds of thousands of pounds of highly variable material. Factors that can influence nutrient content of feeds and forages include variety, maturity at harvest, fertilization strategy, soil type, precipitation, temperature, and storage. Therefore, it should be no surprise that sampling error represents one of the largest sources of variation in feed analysis (Whitesides and Chandler, 1998). These errors can result in reduced livestock performance and lost revenue by buyers or sellers of feeds. Sampling variation can be reduced to acceptable levels by following specific sampling protocols as described by Meehan and Sedivec (2018).

What kind of analyses do you need?

Analytical packages and prices will vary from one lab to another. Feed samples are analyzed using either wet chemistry or NIRS (near infrared reflectance spectroscopy). Wet chemistry utilizes heat and chemicals to break down and isolate nutrients in the sample. It requires a skilled technician and is usually more costly but also more accurate. Wet chemistry is still considered the "gold standard" when it comes to analyses.

The process of NIRS utilizes infrared light in a spectrophotometer to quantify nutrient content. Values for different types of feed are determined by comparing light wavelengths from samples of known nutrient values that were established by wet chemistry procedures. Accuracy of NIRS is highly dependent on the calibration methods and feed library available at an individual laboratory. When sending in a sample for NIRS, it is important to identify the type of feed or forage being submitted to ensure the right feed library is used. It is most useful for pure forage samples such as alfalfa or a single grass species. Use of NIRS is not recommended for co-product feeds or for determination of mineral content, nitrate, or potential contaminants such as vomitoxin.

Most laboratories offer a standard feed analysis package that will cost between $20 and $40, depending on the number and type of nutrients being evaluated. In general, dry matter (DM), fiber content, total digestible nutrients (TDN; estimate of energy) and crude protein (CP) are used as the basis to determine feed quality and develop rations for beef cattle at various stages of production. However, it can be worthwhile to evaluate other components of the feed as well. Mineral content is highly variable, so analysis is helpful in determining type and amount of minerals supplied by the basal diet and what type of mineral supplement is needed.

The following explanations define some of the common terms used in feed analysis.

Dry matter – Moisture content of feeds is extremely variable. Using dry matter allows comparisons across feedstuffs and can also give an indication of feed quality (i.e. hay or silage that should be harvested/stored at a given moisture content). Dry matter content is used to compare nutrient content of different feeds on an equal basis and in ration development.

Crude protein – In animal feeds, crude protein is calculated as: nitrogen × 6.25 = CP. This formula is based on the assumption that proteins of typical animal feeds contain approximately 16% nitrogen (100 ÷16 = 6.25). Crude protein is essential for growth processes, milk production, and muscle development. If hay is baled or stacked wet, a chemical reaction called the Maillard Reaction takes place. In this reaction, nitrogen becomes linked to the carbohydrate portion and is unavailable to the animal. If heat damage is suspected, the laboratory may report a value for **unavailable protein, ADF-N, ADF-CP, bound protein,** or **insoluble protein.** Not all labs will report this value unless it exceeds 10% of the total CP content. Use the adjusted CP value for ration formulation if available.

Acid detergent fiber (ADF) – This refers to the cell wall portions of forage made up of cellulose and lignin. Although ruminants can digest cellulose, lignin is closely associated with it and decreases the overall digestibility. Therefore, ADF is often used as a measure of digestibility….the higher the ADF content, the lower the digestibility. Forages with less than 35% ADF would be considered high quality.

Neutral detergent fiber (NDF) – The NDF component contains cellulose and lignin (similar to ADF), but also includes hemicellulose, which is digestible by ruminants. Neutral detergent fiber is often used as an indicator of bulk and can be used to estimate dry matter intake (DMI). Beef cows can consume approximately 1% of their body weight as NDF. For example, a 1300 lb. cow could consume 13 lbs. of NDF. If a forage contains 55% NDF, maximum voluntary intake of that forage would be estimated at 23.6 lbs. This number could potentially increase if other nutrients such as protein are relatively high, or if this forage was fed to rapidly growing animals or fed during cold conditions. For legumes, NDF < 40% would be considered high quality, while NDF < 50% is considered high quality for grasses.

Total Digestible Nutrients (TDN) – This is a measure of the energy value in a feedstuff. There is no direct way to measure energy because of the multiple components within feeds that supply energy; therefore, TDN is typically estimated based on the sum of the digestible fiber, protein, lipid, and carbohydrate components of a feed. It may also be calculated solely based on ADF content. It is important to understand how TDN is being reported in order to make sure it is as accurate as possible.

Net Energy (NE) – The net energy system separates energy requirements into components used for tissue maintenance (NE_m), gain (NE_g), and lactation (NE_l). These values are typically used when feeding moderate to high levels of concentrate (finishing or dairy diets) to provide a more accurate prediction of animal performance.

Minerals - Many times the only minerals reported in a standard forage analysis are Ca and P; however, most labs do offer a complete mineral analysis package. The macro minerals that are required in larger amounts are reported as a percentage, while trace or micro minerals are reported in parts per million (ppm).

Relative Feed Value (RFV) – This is an index used to rank forages based on ADF and NDF content as compared to full bloom alfalfa which has an RFV of 100. Caution should be used when interpreting RFV of grass hay. Fiber digestibility is different between grasses and legumes, and these differences are not accounted for in the RFV equation.

Relative Forage Quality (RFQ) – This equation is similar to RFV, but incorporates the digestibility and TDN of forages. The RFQ index is an improvement over the RFV index for those that buy and sell forages, and it better reflects the performance that can be expected from cattle fed those forages. One other advantage of the RFQ prediction is that it accounts for differences in fiber digestibility between grasses and legumes.

The lab results are in; now what?

The first step is to estimate available hay and feed needs. There are a variety of factors that influence how much forage a cow will eat every day. Weight, stage of production (growth, pregnancy, lactation), and environmental factors will play a key role, in addition to forage quality. As forage quality increases, the amount of forage a cow can consume will also increase due to increased digestibility and availability of nutrients. Here are some general guidelines for estimating dry matter intake (DMI) of forages based on energy content:

- Low quality forage (<52% TDN)
  - 1.8% of body weight for dry cows and 2.2% of body weight for lactating cows
- Medium quality forage (52-59% TDN)
  - 2.2% of body weight for dry cows and 2.5% of body weight for lactating cows
- High quality forage (>59% TDN)
  - 2.5% of body weight for dry cows and 2.7% of body weight for lactating cows

For example, if hay provides 55% TDN and dry cows average 1,350 pounds, they could consume 29.7 pounds of hay on a dry matter basis. In order to determine the daily amount fed, divide the dry matter amount in pounds by the dry matter percentage of the hay. If the hay is 88% dry matter, the as-fed amount of forage would be 33.8 pounds per cow per day (29.7 pounds dry matter ÷ 0.88). If there are 200 cows in the herd, the herd would require 6,570 pounds per day (3.4 tons). This should be multiplied by an estimate of the total number of feeding days to determine total hay needs. It is a good idea to include a longer feeding period to try to account for weather uncertainty.

Storage and feeding losses should also be included in calculations to ensure that adequate hay supplies are available. If stored outside, dry matter losses could approach 20%. If stored inside, losses will decrease to around 7%. Feeding losses vary widely depending on the feeding system. When hay is fed in bunks, waste may be as low as 3-14%. If bales are rolled out on the ground, losses due to trampling and overconsumption may be as high as 24-45%, particularly when cattle are fed for multiple days at one time. With free choice access to large quantities of forage, intake will increase by 15-20% beyond what is needed to meet requirements. If conditions allow, daily feeding helps force cattle to eat hay that might otherwise be wasted. If you are paying $150/ton for hay and you could cut waste by 25% just by covering the hay and feeding on a daily basis, this would result in savings of around $40/ton. At that rate, it shouldn't take long for the savings to add up to allow for investing in extra equipment such as feed bunks or maybe even a bale processor or feed wagon.

Forage analysis results can be combined with an estimate of animal nutrient requirements based on stage of production. In general, dry mature beef cows in mid-gestation have dietary TDN requirements of 50% and CP requirements of 7%. In late gestation, these requirements increase to 55-58% TDN and 8-9% CP. After calving and during early lactation, requirements are further increased to 60% TDN and 11% CP. These general rules of thumb can be used to determine the best use of different feeds based on stage of production (i.e. feeding the lowest quality hay early and saving the higher quality forage for lactation). It is important to remember that factors such as breed, cow body condition, milk production, age, and environment will influence requirements. Requirements for various classes of livestock based on weight and stage of production can be determined using tables available in the "Nutrient Requirements of Beef Cattle" publication or by using a computerized ration balancing program. The amount of hay (and supplement, if necessary) to be provided should be adjusted based on changing requirements at various stages of production. Depending on your comfort level, you can go through this process on your own, or consult with an Extension professional or nutritionist.

One additional concept that helps determine the true value of feedstuffs is by using price of the feed and nutrient content to determine the cost per pound of the major nutrients. For example, consider corn at $3.50 per bushel (56 lbs./bushel), 90% DM, 88% TDN, and 8% CP. Cost per pound of nutrient can be determined by following the steps below:

- Calculate lbs. of DM for each unit
  - 2000 lbs. x 0.9 = 1800 lbs. DM
- Calculate lbs. of nutrients supplied
  - 1800 lbs. * 0.88 = 1584 lbs. TDN
  - 1800 lbs. * 0.08 = 144 lbs. CP
- Calculate cost per lb. of nutrients supplied ($3.50/bu, 56 lb/bu)
  - $125/ton ÷ 1584 = $0.08 per lb of TDN
  - $125/ton ÷ 144 = $0.86 per lb of CP

When choosing the best feed or combination of feeds for a given situation, the cost of trucking or freight should be included. During a drought in a given area, hay and feeds are often available in other parts of the country. Although they may appear to be an economical choice, the additional cost of having them delivered may make them more expensive. A simple method to account for the cost of shipping is to take the cost of shipping the load, divide by the total weight of the load, and then add it to the cost per ton of feed. This will allow you to assess the true cost of the feed. Other considerations when comparing feed costs might include processing, storage and machinery requirements, and feeding limitations.

Summary

Proper sampling and analysis of feeds is one of the most important aspects of an efficient and effective nutritional management program for livestock. Understanding of nutrient content through analysis is necessary to avoid negative impacts on performance and profitability due to over- or under-feeding. Because of wide variation in nutrient quality of feeds, this information is necessary to balance rations and provide the most appropriate feeds to each class of livestock based on specific nutrient requirements. Results of laboratory analysis can also be used to develop least-cost rations and determine market value of feeds.

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