# Understanding & Significance of Forage Analysis Results

(unless otherwise noted, the following information pertains to ruminants, cattle in particular).

**Moisture** – the percent water in a sample.

**Dry matter** – equals (100% - Moisture) and represents everything in the sample other than water including protein, fiber, fat, minerals, etc.. Animals consume feeds to meet their dry matter needs, because it is the dry matter that contains all of the nutrients. Therefore, animals will have to consume more of a wetter feed to receive the same amount of dry matter as they would from a drier feed. For example, if an animal consumes 20 lbs. of hay at 90% dry matter, it consumes 18 lbs. of dry matter (20 x .90). If haylage at 40% dry matter was to be substituted for the hay, it would have to consume 45 lbs. of haylage (18/.40) to receive the same amount of dry matter.

Thus, it is very important to know the dry matter content of a feed to establish feeding rates and insure that livestock receive the proper amount of feed to meet their daily needs.

**As Sampled Basis** – nutrient results for the sample in its natural state including the water. Also known as as fed or as received.

**Dry Matter Basis** – nutrient results for the sample with the water removed. There is considerable variation in the moisture content of forages. Removing the water eliminates the dilution effect of the water thereby enabling direct comparisons of nutrient contents across different forages. For example, suppose that you wanted to compare the protein content of a hay testing 90% dry matter to a haylage testing 40% dry matter. On an as sampled basis the hay tested 14% crude protein (CP) and the haylage 8% CP. The hay appears to have the higher CP level. However, removing the dilution effect of the water reveals that the hay is 15.5% CP (14/.90) and the haylage is 20% CP (8/.40) on a dry matter basis. Thus, removing the dilution effect of the water revealed that per pound of dry matter, the haylage is higher in protein. Animals eating the haylage will consume more protein per pound of dry matter than they will from the hay.

Livestock nutrient requirements may be expressed on either an as sampled or dry matter basis. It is important to use analytical results expressed on the same basis as the nutrient requirements. In general, most livestock requirements are expressed on a dry matter basis, therefore, the forage results on a dry matter basis should be used to balance the ration. Again, the key point is to make sure that the requirements and results are expressed on the same basis.

## Protein and Protein Fractions

**Crude Protein (CP)** – the total protein in the sample including true protein and non-protein nitrogen. Proteins are organic compounds composed of amino acids. They are a major component of vital organs, tissue, muscle, hair, skin, milk and enzymes. Protein is required on a daily basis for maintenance, lactation, growth and reproduction. Proteins can be further fractionated for ruminants according to their rate of breakdown in the rumen.

**Urea and Ammonia** – reported as crude protein equivalent (CPE). Urea and ammonia are not proteins. However, they contain nitrogen that can be used by the microbial population in the rumen to synthesize protein. They are classified as non-protein nitrogen (NPN). Thus, although they are not true proteins, they supply nitrogen which can be used to form microbial protein and therefore have a certain value that is equivalent to protein for ruminants. The reported result is the CPE contribution from each of these compounds. The results are not the percent urea or ammonia in the feed. The actual percentage in the feed can be calculated by dividing the urea CPE by 2.81 or the ammonia CPE by 5.15. The urea and ammonia appear in the soluble protein fraction of the protein.

**Soluble Protein (SP)** – proteins and non-protein nitrogen that are rapidly broken down in the rumen. They are used to synthesize microbial protein in the rumen.

**Degradable Protein (RDP)** – consists of the soluble protein and proteins of intermediate ruminal degradability. They are used to synthesize microbial protein in the rumen.

**Undegradable Protein (RUP)** – proteins that have a slow rate of degradability and escape digestion in the rumen. UIP is also known as escape or bypass protein and reaches the lower gastrointestinal (GI) tract essentially intact. The undegradable protein is broken down in the GI tract as it would be in nonruminants.

**Acid Detergent Insoluble Crude Protein (ADICP)** – also known as heat damaged or unavailable protein. Typically caused by heating during fermentation or drying, a portion of the protein reacts with carbohydrates to form an indigestible complex rendering it unavailable for digestion. ADICP escapes ruminal breakdown and represents the portion of the undegradable protein that is unavailable to the animal.

**Neutral Detergent Insoluble Crude Protein (NDICP)** – it has been suggested that the NDICP represents the portion of the undegradable protein that is available to the animal.

## Carbohydrates

**Neutral Detergent Fiber (NDF)** – a measure of hemicellulose, cellulose and lignin representing the fibrous bulk of the forage. These three components are classified as cell wall or structural carbohydrates. They give the plant rigidity enabling it to support itself as it grows, much like the skeleton in animals. Hemicellulose and cellulose can be broken down by microbes in the rumen to provide energy to the animal. NDF is negatively correlated with intake.

**Acid Detergent Fiber (ADF)** – a measure of cellulose and lignin. Cellulose varies in digestibility and is negatively influenced by the lignin content. As lignin content increases, digestibility of the cellulose decreases. ADF is negatively correlated with overall digestibility.

**Lignin** – undigestible plant component. Lignin has a negative impact on cellulose digestibility. As lignin content increases, digestibility of cellulose decreases thereby lowering the amount of energy potentially available to the animal.

**Crude Fiber (CF)** – historical method of fiber analysis used to divide carbohydrates into digestible and indigestible fractions. Crude fiber accounts for most of the cellulose and only a portion of the lignin. It is not the most accurate method for quantifying fiber, particularly for forages. However, given that grains are low in lignin, it is a reasonable estimate of fiber in grains and is still used today as the legal measurement of fiber in grains and finished feeds.

**Pectin** – a cell wall polysaccharide that functions as "cellular glue". Also known as "soluble fiber", it possesses the rapid and extensive degradation characteristics of nonstructural carbohydrates, yet without the propensity to lower rumen pH or cause lactic acidosis.

**Starch** – a polysaccharide found primarily in the grain or seed and/or root portions of plants. Starch is a good source of energy.

**Water Soluble Carbohydrates (WSC) –** carbohydrates solubilized and extracted in water. Includes monosaccharies, disaccharides and some polysaccharides (mainly fructan). Fructan is a major storage carbohydrate in grasses.

**Ethanol Soluble Carbohydrates (ESC)** – carbohydrates solubilized and extracted in 80% ethanol. Includes primarily monosaccharides and disaccharides.

**Non Fiber Carbohydrates (NFC)** – non-cell wall carbohydrates consisting of starch, sugar, pectin and fermentation acids that serve as energy sources for the animal. In ruminants, NFC are broken down by the microbial population in the rumen and used as an energy source. NFC is calculated as 100% - (CP% + (NDF% - NDICP%) + Fat% +Ash%).

## Fat

**Fat** – typically determined by ether extraction. In addition to fat, ether extraction may solubilize plant pigments, esters and aldehydes. This is why the measurement is called crude fat. Fat is an energy dense nutrient and contains 2.25X to 2.8X the energy found in carbohydrates. Fat is added to rations to boost energy levels when intake may be limiting.

## Energy

Energy is the nutrient required in the greatest amount. Energy is used in all biological processes and is essential for life. For livestock, energy requirements are determined for maintenance, growth or gain, lactation, reproduction and activity level. Failure to supply adequate energy will result in poor performance. Energy values are not measured, rather they are predicted using equations and relationships with other nutrients. Dairy One uses a multiple component summative approach for its ruminant energy prediction system. Energy contributions from protein, fiber, nonstructural carbohydrates and fat form the foundation of the system. Discounts are applied to reflect energy available for productive purposes.

### Ruminants

**Total Digestible Nutrients (TDN)** – denotes the sum of the digestible protein, digestible NSC, digestible NDF and 2.25X the digestible fat.

**Gross Energy** – the total energy value of a feed before accounting for losses due normal digestive, metabolic and productive functions.

**Digestible Energy (DE)** – equals gross feed energy minus energy lost in the feces.

**Metabolizable Energy (ME)** – equals gross feed energy minus energy lost in the feces, urine and gases.

**Net Energy for Lactation (NEl)** – an estimate of the energy value of a feed used for maintenance plus milk production during lactation and for maintenance plus the last two months of gestation for dry, pregnant cows.

**Net Energy for Maintenance (NEm)** – an estimate of the energy value of a feed used to keep an animal in energy equilibrium, i.e., neither gaining or losing weight.

**Net Energy for Gain (NEg)** – an estimate of the energy value of a feed used for body weight gain above that required for maintenance.

**SS NEl** – corn silage NEl value adjusted for starch digestibility using the Schwab-Shaver adjustment factors.

**SS Proc. NEl** – corn silage NEl value adjusted for starch digestibility as described above plus the effect of whole plant processing.

**NRC 2001 Energy Table** – energy values determined using the system described in the 2001 NRC Dairy Cattle publication. The NEl table reflects the decline in energy value of a feed associated with increasing levels of milk production, dry matter intake and rate of passage.

### Horses

**Total Digestible Nutrients (TDN)** – denotes the sum of the digestible protein, digestible nitrogen-free extract (NFE), digestible crude fiber and 2.25X the digestible fat. TDN is estimated from digestible energy (DE).

**Digestible Energy (DE)** – equals gross feed energy minus fecal energy. It is predicted from ADF and CP for forages and ADF for grains.

### Minerals

**Ash** – a measure of the total mineral content. Samples are weighed and incinerated at 600oC for two hours. This burns off all of the organic material (protein, fiber, fat, etc.) leaving behind the minerals. The ash residue weight is then divided into the original weight to determine the percent ash.

**Calcium (Ca)** – bone and teeth formation, blood clotting, muscle contractions, milk component, transmission of nerve impulses, cardiac regulation, activation and stabilization of enzymes.

**Phosphorus (P)** – bone and teeth formation, key component of energy metabolism, milk component, body fluid buffer systems.

**Magnesium (Mg)** – enzyme activator, found in skeletal tissue and bone, neuromuscular transmissions.

**Potassium (K)** – osmotic pressure regulation and water balance, electrolyte balance, acid-base balance, enzyme activator, muscle contraction, nerve impulse conductor.

**Sodium (Na)** – Acid-base balance, muscle contraction, nerve transmission, maintenance of body fluid balance, osmotic pressure regulator, cellular uptake of glucose, amino acid transport.

**Iron (Fe)** – hemoglobin and oxygen transport, enzyme systems.

**Zinc (Zn)** – enzyme activator, wound healing, skin health, some impact on udder health (reduced somatic cell counts (SCC)).

**Copper (Cu)** – required for hemoglobin synthesis, coenzyme functions.

**Manganese (Mn)** – growth, bone formation, enzyme activator, fertility.

**Molybdenum (Mo)** – part of enzyme xanthine oxidase, antagonistic and interactive effects with copper and sulfur.

**Sulfur (S)** – needed for microbial protein synthesis, especially when non-protein nitrogen (NPN) is fed.

**Chloride (Cl-)** – acid-base balance, osmotic pressure regulation, component of gastric secretions.

**Cobalt (Co)** – required for vitamin B12 synthesis.

**Selenium (Se)** – component of glutathione peroxidase enzyme, antioxidant properties, prevention of white muscle disease and retained placenta.

### Other

**In Vitro True Digestibility (IVTD)** – an anaerobic fermentation performed in the laboratory to simulate digestion as it occurs in the rumen. Rumen fluid is collected from ruminally cannulated high producing dairy cows consuming a typical total mixed ration (TMR). Forage samples are incubated in rumen fluid and buffer for a specified time period at 39oC (body temperature). During this time, the microbial population in the rumen fluid digests the sample as would occur in the rumen. Upon completion, the samples are extracted in neutral detergent solution to leave behind the undigested fibrous residue. The result is a measure of digestibility that can be used to estimate energy.

**Neutral Detergent Fiber Digestibility (NDFD)** – The proportion of NDF potentially available as determined by an in vitro incubation. NDFD is expressed as a percentage of the NDF. The NDFD can be used to rank forages on potential fiber digestibility and in energy calculations.

**Relative Feed Value (RFV)** – an index for ranking forages based on digestibility and intake potential. RFV is calculated from ADF and NDF. A RFV of 100 is considered the average score and represents an alfalfa hay containing 41% ADF and 53% NDF on a dry matter basis. The higher the RFV, the better the quality.

Due to the inherent variability of measuring ADF and NDF, absolute RFV values should not be used for making direct comparisons or pricing of forages. Rather a range of RFV values should be used to classify a forage. For example, if a RFV of 150 is the target value, any forage testing between 145 to 155 should be considered to have an equivalent value. A good rule of thumb is to accept anything within at least +/- 5 points of the target value.

**Relative Forage Quality (RFQ)** – an index for ranking forages based on a more comprehensive analysis than RFV. RFQ is calculated from CP, ADF, NDF, fat, ash and NDF digestibility measured at 48 hours. It should be more reflective of the feeding value of the forage. RFQ is based on the same scoring system as RFV with an average score of 100. The higher the RFQ, the better the quality.

**Milk lbs./ton** – a projection of potential milk yield per ton of forage dry matter based on digestibility and energy content of the forage.

**Nitrates (N03)** – can be come a problem when fed in high amounts. Nitrate accumulator plants include sorghum, sorghum sudangrass, sudangrass, weeds and small grain forages. Drought, frost, fertilization and manure application practices are factors that can lead to high nitrate levels. Drought stricken corn silage is particularly susceptible. Nitrates accumulate in the bottom portion of the stalk and it is often recommended that suspect corn silage be chopped higher than usual. Nitrate levels may be reduced by up to 50% by ensiling.

When nitrate is converted to nitrite, it impedes the uptake of oxygen by the blood resulting in death due to lack of oxygen. Blood becomes brownish in color and exterior membranes may become bluish in color.

**pH** – a measure of the degree of acidity. Good corn silage typically has a pH of 3.5 - 4.5 and haycrop silages 3.8 - 5.3.

**Volatile Fatty Acids (VFA)** – primarily lactic, acetic, propionic and butyric acids produced as a result of microbial fermentation in silage or the rumen.