# Understanding Your CVAS Forage Laboratory Report

This document is broken down into two sections. The first is a review of terms and nutrients that are either newer or somewhat unique to CVAS reporting. The second, starting on page 2, is a comprehensive review of nutrient definitions and common terms used in animal feeding and nutrition. If you don't see a definition that you are seeking in the first section, scroll down through the alphabetical listing in the second section.

### Lab ID
A unique number assigned by CVAS specific to the sample analyzed. This number is important to include in all correspondence with the lab concerning the sample.

### Series
If the client submits the sample via our mobile app or through the web site, a sample can be identified as coming from a specific source. Subsequent samples can be tagged by this source name, creating a "series", which allows for automated summarization of samples.

### Version
All reports start with a version number of "1.0". If a sample is reprocessed for any reason (a new test was added or a nutrient was rechecked, for example) the version number will increment. This allows the lab and the client to track any changes to the initial report. If a report is simply reprinted, or sent out again, the version number does not change but this new printing is reflected in an updated report date.

### Feed Type
The feed type is assigned by the laboratory based on the sample description provided by the client, by visual observation, and through nutrient evaluation.

### NDF Digestion Rate (Kd, %HR, Van Amburgh, Lignin * 2.4)
This value is the estimate of NDF digestion rate based on research by Dr. Van Amburgh of Cornell University. It utilizes an estimate of indigestible fiber necessary for this calculation as "lignin %DM * 2.4" for all feed types

### NDF Digestion Rate (Kd, %HR, Van Amburgh, iNDF)
This value is the estimate of NDF digestion rate based on research by Dr. Van Amburgh of Cornell University. In contrast to estimating indigestible NDF as "lignin * 2.4" it utilizes a directly determined indigestible NDF value. The directly determined indigestible NDF values are accomplished by incubating feed material for 240 hours in rumen fluid; the residue after NDF treatment and ashing considered to be indigestible NDF. This approach provides a definition of indigestible fiber that is significantly larger than the "lignin * 2.4" approach. With a larger indigestible pool and smaller digestible pool of NDF, calculated rates of degradation will be considerably higher.

### Starch Digestion Rate (kd, %HR, Mertens)
Rumen starch digestibility is estimated from a 7 hour incubation of a starch containing feed material, ground to 4 mm. This starch digestibility is then modeled in an equation developed by Dr. Dave Mertens to generate an estimated rate of rumen starch digestibility. This value should fall in the range of 15% to 30% / hour.

### CNCPS / CPM Lignin Factor
The CNCPS and CPM models make use of the lignin value from a forage report to estimate indigestible fiber as "lignin x 2.4" and do not allow for input of a directly determined indigestible NDF. In order to "input" an indigestible NDF value, the lignin value must be modified. The "CNCPS / CPM Lignin Factor" would be the revised lignin that would be entered in order to calculate the reported indigestible NDF value.

## Summative Index

This value is provided on most NIR forage reports and some chemistry reports. It represents the sum of all of the constituents of the dry matter that were measured. For NIR reports, this index can be a measure of the reliability of the overall analysis. Values should fall generally in the range of 98% to 103%. If the index falls significantly outside of this range, the user may want to evaluate the analysis more critically and consider whether the samples is better run by chemistry methods. Call CVAS if you have further questions regarding this index.

*The following information is adapted from a College of Agricultural and Environmental Sciences publication "Common Terms Used in Animal Feeding and Nutrition, B 1367."*

## Acid Detergent Fiber (ADF)

The fibrous component represents the least digestible fiber portion of forage or other roughage. This highly indigestible part of forage includes lignin, cellulose, silica and insoluble forms of nitrogen but not hemicellulose. Forages with higher ADF are lower in digestible energy than forages with lower ADF, which means that as the ADF level increases, digestible energy levels decrease. During laboratory analysis, ADF is the residue remaining after boiling a forage sample in acid detergent solution. ADF is often used to calculate digestibility, total digestible nutrients (TDN) and/or net energy for lactation (NEl).

## Acid Detergent Insoluble Crude Protein (ADICP) or Acid Detergent Fiber-Crude Protein (ADFCP)

ADICP (or ADFCP) is the insoluble protein fraction remaining in the acid detergent fiber residue of a feed sample. ADICP escapes ruminal breakdown and represents the portion of the protein that is not degradable and is therefore unavailable to the animal. It also contains any heat-damaged protein that may result from heating during storage or processing. In this case, a portion of the protein reacts with carbohydrates (fiber) to form an indigestible complex, rendering it unavailable for digestion. This parameter is also reported as acid detergent insoluble protein (ADIP), acid detergent insoluble nitrogen (ADIN) or acid detergent fiber protein (ADFP). It is expressed as a percent of crude protein. It is an adequate estimate of heat-damaged protein in forage feeds but not in non-forage feeds (Nakamura et al., 1994).

## Aflatoxins

Fungal or mold growth in or on foods and feed can result in the production of many different types of toxic biochemicals. As a group, these toxic substances are commonly called mycotoxins. The term aflatoxins refers to a particular group of mycotoxins produced by some species of the genus Aspergillus. There are four major aflatoxins named B1, B2, G1, G2 plus two additional metabolic products known as M1 and M2 that are of significance as direct contaminants of foods and feeds.

Fungal (or mold) growth and aflatoxin contamination are the consequence of interactions among the fungi, the host (foods or feeds) and the environment. On a standing crop, aflatoxin contamination of peanuts and corn is favored by high temperatures, prolonged drought conditions and high insect activity, while postharvest production of aflatoxins on corn and peanuts is favored by higher water content, warm temperatures and high humidity. Forages are generally not analyzed for aflatoxins but in some situations (e.g., corn or sorghum silage that is at risk) this analysis may be warranted.

The presence of aflatoxins in feeds, forages and foods is an important anti-quality factor and is associated with various diseases in livestock, domestic animals and humans that are broadly termed aflatoxicosis. Aflatoxicosis is primarily a hepatic (liver) disease. Liver damage, decreased reproductive performance, reduced milk or egg production, embryonic death, teratogenicity (birth defects), tumors and suppressed immune system function are caused by aflatoxins even when low levels are consumed.

The FDA's (Food and Drug Administration) action level for human food is 20 ppb total aflatoxins, with the exception of milk, which has an action level of 0.5 ppb for aflatoxin M1. The FDA action level for most feeds is also 20 ppb (Table 1).

**Table 1. FDA Action Levels for Aflatoxins***

| Commodity | Action level (µg/kg or ppb) |
|---|---|
| All products, except milk, designated for humans | 20 |
| Milk | 0.5 |
| Corn for immature animals and dairy cattle | 20 |
| Corn for breeding beef cattle, swine and mature poultry | 100 |
| Corn for finishing swine | 200 |
| Corn for beef cattle | 300 |
| Cottonseed meal (as a feed ingredient) | 300 |
| All feedstuff other than corn | 20 |

*According to compliance policy guides 7120.26, 7106.10 and 7126.33

If the level of aflatoxins in forage is higher than the action level, it may be fed in combination with other feeds containing low levels of or no aflatoxins.

### Amino Acids

A class of nitrogen-containing molecules containing an amine group, a carboxylic acid group and a side chain that varies between different amino acids. Amino acids are the building blocks from which protein is made in the body. There are 20 known standard amino acids forming various proteins. When taken up into the body in the diet, the 20 standard amino acids are either used to synthesize proteins and other biomolecules or broken down into urea and carbon dioxide. Of the 20 standard amino acids, eight are called essential amino acids and the other 12 are called non-essential amino acids. Animals (including humans) cannot synthesize the essential amino acids from other compounds at the level needed for normal growth, so they must be obtained from food (hence they are called essential amino acids).

### Anti-quality Factors

Apart from nutrients, forages may contain various harmful compounds that can adversely affect animal performance and cause sickness or even death. These compounds are called anti-quality factors and include tannins, nitrates, alkaloids, cyanoglycosides, estrogens and mycotoxins. The occurrence and/or severity of these factors depend on the forage and weed species present, season, environmental conditions and sensitivity of the animal. High-quality forages should be free from harmful levels of anti-quality components.

### Ash

The residue containing inorganic mineral elements of a feed sample, determined in a laboratory by burning the sample at a high temperature (removing the organic matter) and weighing the residue (i.e., ash).

### As-fed Basis

Feed analyses reports often state results based on the feed's natural state (i.e., including water) and/or on a dry matter basis. The term "As-fed Basis" is used to alert the reader that the analytical results of a feed sample are based on its natural state including water. That means it is affected by the sample's moisture level before drying. This may also be referred to by the terms "As-is Basis" or "As-received Basis." When comparing two or more analyses, it is generally best to utilize the data from the "Dry Matter Basis" rather than the "As-fed Basis" unless you are mixing a ration for feeding.

## Balanced Ration
Complete feed formulated to provide a specific animal species and class with appropriate amounts of all nutrients required for maintenance and a given level of performance.

## Botulism
Botulism is a muscle-paralyzing disease caused by botulinum toxin, a potent neurotoxin produced mainly by the bacterium Clostridium botulinum and also by a few strains of C. baratii and C. butyricum. Clostridium botulinum is an anaerobic (can only grow under anaerobic conditions) bacterium that usually grows when the pH of the growing medium is greater than 4.6.

Botulism can result from the ingestion of the toxin or the growth of C. botulinumon anaerobic food/feed tissues. Seven types of botulinum toxin, designated A through G, have been identified. Types A, B, E and F cause illness in humans. Type C is the most common cause of botulism in animals. Type D is sometimes seen in cattle and dogs, and type B can occur in horses. Types A and E are found occasionally in mink and birds. Type G rarely causes disease, although a few cases have been seen in humans. All types of botulinum toxin produce the same disease; however, the toxin type is important if anti-toxin is used for treatment.

The toxins come from a variety of sources. Decaying vegetable matter (e.g., grass, hay, grain, spoiled silage) and carcasses can cause botulism in animals. Ruminants may inadvertently be fed hay or silage contaminated by carcasses of birds or mammals that may contain the toxin. Horses usually ingest the toxin in contaminated forage.

Botulinum toxins are large proteins that can be easily denatured. Toxins exposed to sunlight are inactivated within one to three hours. Botulinum can also be inactivated by 0.1% sodium hypochlorite, 0.1 M NaOH, heating to 80°C for 30 minutes or 100°C for 10 minutes. Chlorine and other disinfectants can destroy the toxins in water.

## By-pass Protein
The portion of intake protein that has a slow rate of degradability in the rumen. It is fed so that it may escape digestion in the rumen, reach the lower gastrointestinal (GI) tract essentially intact and be digested directly in the small intestine as it would be in non-ruminants. This can provide a balance of amino acids unaltered by microbial digestion and synthesis. By-pass protein is also known as undegradable intake protein (UIP), rumen undegradable protein (RUP) or escape protein.

## Carbohydrates
Carbohydrates are biochemical compounds composed only of the elements carbon, hydrogen and oxygen, and are the main source of energy for animals. Animals get the majority of their required energy from the carbohydrates in feeds. Carbohydrates are polymers made of basic sugar units, such as glucose (the most abundant), fructose, galactose, etc. The two major classes of carbohydrates in plants are known as non-structural and structural. Those that serve as storage and energy reserves and that are available for more rapid metabolism to supply energy (e.g., sugars, starch, and pectin) are referred to as non-structural carbohydrates. Those carbohydrate fractions that are not used for energy storage and provide fiber and anatomical features for rigidity and even water transport are known as structural carbohydrates (e.g., fibrous cellulose and hemicellulose). Non-structural carbohydrates are more available for energy metabolism than the structural carbohydrates.

## Cellulose
Cellulose is a major structural carbohydrate that is present in plant cell walls. Cellulose is an unbranched chain of 7,000 to 15,000 glucose molecules that are linked together by ß-1,4 bonds. Cellulose is a major part of the structural fiber in forages and can be utilized by microorganisms in the rumen. When utilizing the chemistry associated with the Van Soest Detergent Fiber Fractions, cellulose is estimated as follows:
Cellulose = ADF – (ADL + Ash), where ADF is acid detergent fiber and ADL is acid detergent lignin

## Concentrates
Concentrates refer to animal feeds that are rich in energy and/or protein but low in fiber, such as corn, soybean meal, oats, wheat, molasses, etc.

## Crude Fat
Crude fat is an estimate of the total fat content of feeds taken from older collection of methods known as proximate methodology. The crude fat is estimated using ether extraction. Crude fat contains true fat (triglycerides) as well as alcohols, waxes, terpenes, steroids, pigments, ester, aldehydes and other lipids. See Ether Extract and Fat.

## Crude Fiber (CF)
This older proximate method was used to divide carbohydrates into digestible and indigestible fractions. When CF content is higher, the energy content of the feed is lower because crude fiber is considered indigestible. Measuring crude fiber was one part of the original system of analyzing the "digestible" fraction in feedstuffs. This method uses sequential acid and alkali extraction. It was developed by Henneberg and Sttohmann during the 1860s at the Weende Experiment Station in Germany, and is often referred to as the Weende System of proximate analysis. The CF extract was once used as a standard analysis for fibrous parts or the indigestible portion of carbohydrates in feeds. However, some of these substances are partially digestible by microorganisms in the rumen. Crude fiber accounts for most of the cellulose but only a portion of the lignin and no ash, so it underestimates true fiber and is less than acid detergent fiber (ADF). Thus, CF is not a good indicator of digestibility in ruminant animals, and the use of this parameter in feeds for ruminants is declining.

Even though CF is not a very useful parameter for quantifying forage fiber where lignin content is substantial, the CF is a reasonable estimate of the fiber in grains because of their low lignin content. Thus, it is still commonly used for analysis of feeds for non-ruminants or monogastric animals (i.e., those that do not have a chambered stomach or rumen; for example, horses and pigs). Crude fiber is still used today as the legal measurement of fiber in grains and finished feeds. See Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) for contrast.

## Crude Protein (CP)
Proteins are organic compounds composed of building blocks called 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.

The crude protein content of a feed sample represents the total nitrogen (N) in the diet, which includes not only true protein but also non-protein nitrogen (e.g., urea and ammonia in a feed; nitrate is not included in non-protein nitrogen). Because N is an integral part of any amino acid, non-protein nitrogen has the potential to be utilized for protein synthesis by rumen microorganisms. In laboratory analysis, total N present in a feed sample is first determined and then the total amount of protein is calculated by multiplying the total N by a factor. This factor is 6.25 for forages because leaf and stem tissue proteins generally contain 16 percent nitrogen, or one part nitrogen to 6.25 parts protein. For seeds, this factor is different (e.g., 5.70 for wheat and 5.90 for other cereal grains). Unless otherwise stated, protein values given in lab reports, feed tables and feed tags are crude protein.

Because the protein content of forages, silages or grains used in animal feeding are sometimes inadequate to meet the needs of the animal class, protein supplements become essential. Consequently, analysis for total protein or crude protein in a feed sample is important.

Crude protein in feeds for ruminants can be further fractionated according to their rate of breakdown in the rumen, as discussed below for neutral detergent fiber insoluble crude protein (NDFICP) and discussed previously for acid detergent fiber insoluble crude protein (ADFICP).

No doubt, CP is an important indicator of the protein content of a forage crop, and even estimates of non-protein nitrogen are important in evaluating nutritive value. However, it is a false perception that protein is always the most limiting nutrient in the animal's diet and CP is the ultimate measure of a forage quality. In fact, the energy value of forages is often the most limiting attribute for meeting an animal's requirements in most forage-based feeding. An overemphasis on CP may cause one to fail to pay due attention to meeting energy requirements. Furthermore, CP is merely an estimate of nitrogen content (N, % × 6.25 = CP, %) and must be considered in context of plant maturity, species, fertilization rate and many other characteristics. For example, a high nitrate concentration in the forage will result in an artificially high CP level.

### Degradable Intake Protein (DIP)

The DIP, also called Rumen Degradable Protein (RDP), represents the portion of intake crude protein (CP) that can be digested or degraded to ammonia and amino acids in the rumen by microbes. This fraction of CP consists of non-protein nitrogen (e.g., urea and ammonia in treated silage) plus the true proteins that are soluble and those having intermediate ruminal degradability. They are used to synthesize microbial protein in the rumen. The RDP or DIP is expressed as a percentage of CP, where DIP = NPN + Soluble True Protein + True Protein of Intermediate Degradability.

### Detergent Fiber Analysis

Since crude fiber (CF) has been found to have an unsatisfactory relationship with animal performance, it has limited value in ruminant nutrition. Most feed analysis laboratories do not use the proximate analysis system (of which CF was a part) and have replaced it with the Van Soest detergent fiber analysis system. The technique of using detergents to separate digestible and indigestible parts of plant tissues was originally proposed by Van Soest in 1963. The concept behind the detergent fiber analysis is that plant cell substances can be divided into less digestible cell walls (made of hemicellulose, cellulose and lignin) and the highly digestible cell contents (containing starch and sugars). These two components are successfully separated by using two different detergent systems:

- A neutral detergent solution of sodium-lauryl sulfate ($C_{12}H_{25}NaO_4S$) in disodium ethylenediaminetetraacetate ($C_{10}H_{14}N_2Na_2O_8$) and sodium borate ($Na_2B_4O_7$) with pH =7.0 (Van Soest, 1963a); and
- An acid detergent solution of cetyl-trimethyl-ammonium-bromide ($C_{19}H_{42}BrN$) in 1N sulfuric acid (Van Soest, 1963b; Van Soest and Wine, 1967).

In a sequential analysis, the feed sample is initially boiled in the neutral detergent solution to separate the neutral detergent soluble fraction (cell contents) from the neutral detergent insoluble fraction (cell walls). The cell contents are highly digestible (about 98 percent) and include various sugars, starches, pectins and other soluble carbohydrates, proteins, non-protein nitrogenous compounds, lipids, water-soluble minerals and vitamins. The remaining dry matter is estimated and the proportion gives the neutral detergent fiber (NDF).
In sequential analysis, the NDF is then further fractionated by boiling in the acid detergent solution. Hemicellulose is solubilized during this procedure while lignin and cellulose remain insoluble. The residue remaining after boiling NDF in acid detergent solution is called acid detergent fiber (ADF). Cellulose is then separated (i.e., solubilized) by adding sulfuric acid. Only lignin and acid insoluble ash remain after this step. The residue is then combusted in a furnace, and the difference of the weights before and after ashing yields the amount of lignin that was present in the sample. Generally,

- NDF = Hemicellulose + Cellulose + Lignin + Ash
- ADF = Cellulose + Lignin + Ash

Hemicellulose, cellulose and lignin are indigestible in non-ruminants, while hemicellulose and cellulose are partially digestible in ruminants. NDF is a good indicator of the "bulk" fiber and has been used to predict feed intake. In contrast, ADF is a good indicator of digestibility (negatively correlated) and thus energy intake. The detergent fiber analysis system is the most widely accepted method for forage analysis. However, many agencies still base part of their regulations on terms in the proximate. As a result, both methods are used in most laboratories, including the University of Georgia's Feed and Environmental Water Laboratory.

**Digestibility**
Digestibility refers to the extent to which a feedstuff is absorbed in the animal body as it passes through an animal's digestive tract. It varies greatly with the type of feedstuff and type of animal concerned.

**Digestible Dry Matter (DDM) or Dry Matter Digestibility (DMD)**
DDM (or DMD) is the portion of the dry matter in a feed that is digested by animals at a specified level of feed intake. There is no direct laboratory method for measuring DDM/DMD. It is often estimated by measuring in vitro or in situ digestibility. Both of these analyses are rather expensive and laborious. So, in vitro digestibility is frequently estimated by near infrared reflectance (NIR) analysis and/or estimated from the acid detergent fiber. The DDM can be calculated as follows: %DDM = 88.9- [0.779 × %ADF (on a dry matter basis)].

**Digestible Energy (DE)**
Digestible energy provides an indication of the actual amount of energy from a feed that can be available for use by the animal. It is estimated by subtracting energy lost in the feces (fecal energy or FE) from the gross intake energy (GE), (i.e., DE = GE – FE). Digestible energy is commonly used to evaluate poultry and horse feed. For poultry feed, DE is considered as an appropriate measure of feed quality, because FE is almost the sole form of energy loss during digestion. However, in horses, given that FE only partially accounts for the energy losses (considerable losses also occur via urine and gases) in the process of the utilization of nutrients, DE may over estimate low quality feeds relative to high quality feeds.

**Digestible Neutral Detergent Fiber (dNDF)**
The 48-hour in vitro digestible fraction of Neutral Detergent Fiber (NDF) is expressed as a percentage of the dry matter content of a feed sample. Contrast with Neutral Detergent Fiber Digestiblity (NDFD) below.

**Distillers Grains**
Distillers grains are residual grains or byproducts remaining after the starch from grains has been fermented to alcohol. Traditionally, alcohol was produced mainly for beverages by the liquor industry. However, in the last 25 years its use as an alternative fuel has increased significantly. This increased demand has led to the development of ethanol production plants in various places in the U.S. With increasing ethanol production, the opportunity currently exists for using a substantial quantity of distillers grains as feed in livestock industry.

**Dry Matter (DM)**
Dry matter represents everything contained in a feed sample except water; this includes protein, fiber, fat, minerals, etc. In practice, it is the total weight of feed minus the weight of water in the feed, expressed as a percentage. It is determined by drying the feed sample in an oven until the sample reaches a stable weight. This is normally a simple analysis. However, estimates of the DM of fermented materials such as silage are complicated by the presence of volatile fatty acids. These acids are removed in the drying process but they are part of the dry matter and are digestible. This introduces a variable amount of error. Analysis of the fodder without ensiling provides a more accurate estimate of fiber fractions and digestibility contained in the silage.

**Dry Matter Basis**
Dry matter basis indicates the nutrient levels in a feed sample based on its dry matter content (i.e., excluding its water content). This is also referred to as "Dry Basis," "Dry Results" or "Moisture-free Basis." As there is considerable variation in the water content of forages, excluding the water or expressing the nutrient levels on a dry matter basis eliminates the dilution effect of the water, thereby providing the essential common basis for direct comparison of the nutrient contents across different forages.

## Dry Matter Intake (DMI)

Dry matter intake is the amount of (or prediction of the amount of) dry matter consumed by the animal and is a central concept to any discussion of animal nutrition. Typically, intake increases as the digestibility of the forage increases. However, anti-quality components such as tannins and alkaloids in feeds and forages may decrease intake. Scientists have consistently observed that as the percent of neutral detergent fiber (NDF) increases in the feed, animals consume less (i.e., DMI is less). This relationship, along with estimates of NDF digestibility, is used to estimate DMI for grasses and legumes using the following equations:

$DMI_{Grass} = -2.318 + 0.442 \times CP - 0.0100 \times CP2 - 0.0638 \times TDN + 0.000922 \times TDN2 + 0.180 \times ADF - 0.00196 \times ADF2 - 0.00529 \times CP \times ADF$

Where $DMI_{Grass}$ is expressed as % of BW, and CP (Crude Protein), ADF (Acid Detergent Fiber), and TDN (Total Digestible Nutrient) are expressed as % of DM (Moore and Kunkle, 1999).

$DMI_{Legume} = (120 \div NDF) + ([\{NDFD - 45\} \times 0.374] \div 1350) \times 100$

Where $DMI_{Legume}$ is expressed as % of BW, NDF (Neutral Detergent Fiber) as % of DM, and NDFD (48-hour n vitro NDF digestibility) as % of NDF [Mertens (1987) with NDFD adjustment proposed by Oba and Allen (1999)].

Though these calculations have been proven to provide reasonable estimates of DMI, the estimates are not perfect. Dry matter intake is affected by the condition of the animal (e.g., age, body weight, pregnancy status, level of milk production, etc.), feed factors (e.g., palatability, balance of the diet, and anti-quality factors in the feed) and the feeding environment (e.g., temperature and humidity).

## Ensiled

Ensiled refers to the plant materials preserved by anaerobic fermentation and typically stored in a bag, bunker, wrapped bale, or upright silo.

## Ethanol Soluble Carbohydrates (ESC)

ESCs are the carbohydrates that can be solubilized and extracted in 80 percent ethanol. ESC includes primarily monosaccharides and disaccharides.

## Ether Extract

Ether extract is a portion of dry matter extracted with ether. It is a laboratory test to approximate the total fat (or crude fat) content of a feed and includes some waxes, pigments and other lipids to a minor degree in addition to true fats.

## Fat

Chemically, fats are "triglycerides of fatty acids" that are a high-density source of energy for animals. Fat is rich in energy; it contains 2.25 to 2.8 times the energy found in carbohydrates and is highly digestible. Fat is added to rations to boost energy levels when intake may be limited due to poor animal health, less palatable feed or environmental stress. Some concentrates (such as soybean meal) contain relatively high levels of fats and oils. Fats are composed of building blocks called fatty acids. Fats in feed samples are typically determined through ether extraction (EE). In addition to fat, EE may solubilize some other compounds like plant pigments, esters and aldehydes. This is why the measurement of fat through EE is called crude fat. True fat can be measured by determining the content of fatty acids or it can be estimated in forages as ether extract minus one.

## Forage

Forage refers to plants or plant parts other than separated grains fed to or grazed by domestic animals. Forage may be fresh, dry or ensiled (e.g., pasture, green chop, hay, haylage).

**Forage Quality**
Forage quality refers to the ability of a forage to support desired levels of animal performance (e.g., daily gain or milk production). It is a function of voluntary intake and nutritive value (nutrient content and digestibility).

**Gross Energy (GE)**
Gross energy refers to the total energy in a feed before accounting for losses due to normal digestive, metabolic, and productive functions. It is determined by measuring the amount of heat produced when a feed is completely oxidized in a bomb calorimeter. It is not a very useful measure since the gross energy in most common feeds is about the same, but they do not result in similar animal performance. For example, GE in oat grain = GE in oat straw.

**Heat Damage**
Heat damage is the result of exposing the feedstuff to excessive heat during processing or storage, which irreversibly binds protein to the fiber (carbohydrates) portion of the feed through a chemical reaction called "Maillard Reaction" or "Browning Reaction," thus making proteins partially or wholly unavailable for digestion. Also see Acid Detergent Insoluble Crude Protein.

**Hemicellulose**
Like cellulose, hemicellulose is a carbohydrate that exists in almost all plant cell walls along with cellulose. Whereas cellulose is composed only of glucose, hemicellulose is composed of many other sugars (e.g., glucose, xylose, mannose, galactose, arabinose, etc.) in chains of 500 to 3,000 sugar units. Hemicellulose is a branched polymer. In contrast, cellulose is not branched. As hemicellulose content increases in animal feed, the voluntary feed intake typically decreases.

**International Unit (IU)**
A standard unit of potency of a biological agent (e.g., vitamin, hormone, antibiotic, antitoxin); also called a USP unit in the U.S.

**In Vitro**
In vitro (Latin for "within the glass") generally refers to the technique of performing a given biological procedure in a controlled environment outside of a living organism. In other words, it is a process that is carried out in a test tube. In feed testing, in vitro refers to a feed sample that is digested in test tubes or tested outside the animal.

**In Vitro Digestibility or In Vitro Dry Matter Digestibility (IVDMD)**
In vitro digestibility of a feed is determined by incubating a ground feed sample with rumen fluid in a beaker or test tube for 24 to 48 hours, followed either by addition of acid and pepsin and further incubation for 24 hours or by boiling in neutral detergent fiber solution.

**In Situ Digestibility**
In situ digestibility is determined by incubating a ground forage sample in a porous nylon bag placed within the rumen via a fistula or port in the animal's side (in situ) for a fixed time period.

**Laboratory Proficiency**
The appropriateness of the analytical procedures used and the precision of laboratory techniques are determined by many factors (e.g., skills of technicians, quality of the chemicals and water, etc.), which describe the ultimate accuracy and precision of forage analysis. The National Forage Testing Association (NFTA) certifies the proficiency of laboratories with regard to accurately testing hay and corn silage for DM, CP, ADF, NDF, and minerals. Using an NFTA-certified laboratory is a safe option for testing your forages. For a current listing of certified laboratories, as well as more information about proficiency testing, visit NFTA's website (*www.foragetesting.org*). Both the Wet Chemistry and Near Infrared Spectroscopy laboratories of the University of Georgia's Feed and Environmental Laboratory are certified by NFTA.

### Lignin
Lignin is a complex carbohydrate compound, a major structural component of mature plants, contained in the fibrous portion of plant stems, leaves, cobs and hulls. It is undigestible and hence has a negative impact on cellulose digestibility. As the lignin content in a feed increases, digestibility of its cellulose decreases, thereby lowering the amount of energy potentially available to the animal. The term "lignin" was derived from the Latin word "lignum," meaning wood, since it most commonly occurs in the woody tissues of plant materials.

### Lipids
Lipids are substances found in plant and animal tissues that are insoluble in water but soluble in benzene or ether; lipids include glycolipids, phosphoglycerides, fats, oils, waxes and steroids.

### Lysine
Lysine is an essential amino acid for protein synthesis. It is the first limiting amino acid in corn/soybean-based swine diets. It can be added to diets in a synthetic form.

### Macro-minerals
Macro-minerals, also called major minerals, are the elements present in the animal body in relatively larger amounts than micro minerals (thus the name). Therefore macro-minerals are required in relatively large amounts, generally in gram (g) quantities per head per day, if the animal is to live and function properly. Macro-minerals perform specific roles in the body's structure and functions; for example, they help to build body tissues (e.g., bone) or to regulate metabolic activities. Macro minerals interact with each other and must be supplied in proper quantities and ratios to maintain appropriate animal function. The seven macro-minerals essential to animals are: calcium (Ca), phosphorus (P), sodium (Na), magnesium (Mg), potassium (K), sulphur (S), and chlorine (Cl).

The total mineral content of the body is approximately 4 percent of body weight. Calcium makes up approximately 1.75 percent of total body weight, phosphorus makes up approximately 1.10 percent of total body weight, and magnesium makes up approximately 0.04 percent of total body weight.

### Megacalorie (Mcal)
The quantity of energy available in a feed or the amount of energy required for an animal to perform a specific function is most often expressed as a unit of heat, the smallest unit of which is called a "calorie." Because a calorie is too small to express the energy for practical purposes, the energy content of feed is most often expressed in a larger unit called "megacalorie." One megacalorie is one million times larger than one calorie.

- 1,000 Calorie (cal) = 1 Kilocalorie (Kcal)
- 1,000 Kcal = 1 Megacalorie (Mcal)
- Therefore, 1 Mcal = 106 cal

### Metabolizable Energy (ME)
Metabolizable energy equals the gross feed energy minus the energy lost in the feces, urine, and gaseous product of digestion:

- ME = GE – FE (energy in feces) – (energy in urine) – (energy in gases)
- ME = DE (digestible energy) – (energy in urine) – (energy in gases)
- *Because, DE = GE – FE*

Measuring the amounts of energy lost in gaseous form and in the urine is more difficult than measuring the amount lost in feces; therefore, ME value of individual feeds is rarely measured. However, when ME values are needed, nutritionists often use conversion formulas. A commonly used formula to estimate ME in beef feedstuffs is: ME = 0.82 × DE.

**Methionine**
An essential sulfur-containing amino acid involved in many vital enzymatic processes in the human and animal body.

**Micro-minerals**
Micro-minerals, or trace minerals, are present in animal body tissues in extremely low concentrations. They are nutrients required in small amounts, generally in milligram (mg) or microgram (µg) amounts per head per day, but play critically important roles in animal nutrition. There are 10 micro-minerals recognized in animal nutrition: iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), selenium (Se), cobalt (Co), iodine (I), chromium (Cr), molybdenum (Mo) and nickel (Ni). In Georgia, only three of the micro-minerals (copper, zinc and selenium) are likely to be deficient in grazing animal diets. However, copper is particularly toxic in sheep and selenium can also be toxic. Deficiencies and toxic levels are quite regional.

**Milligram per Kilogram (mg/kg)**
Milligram per kilogram is a common unit of concentration representing how many mg of the target substance (i.e., the substance analyzed in the laboratory) are present in one kg of the sample. Since one mg is one-millionth of a kg (or 1 kg is 1 million mg), mg/kg is equivalent to parts per million (ppm). For example, a 20 mg/kg calcium concentration in a feed sample is equal to 20 ppm calcium.

**Minerals**
In feed analysis, minerals refers to inorganic feed elements essential for life.

**Monogastric**
Animals having a single compartment or simple stomach system (e.g., swine, horse). Contrast with rumen and ruminants.

**Mycotoxins**
Mycotoxins are toxic to animals, and are produced on plants by fungi, particularly during weather stress during the growing or harvest seasons or during feed storage (e.g., vomitoxin, zearalenone, aflatoxin, and T-2).

**National Research Council (NRC)**
The NRC is a scientific body in the U.S. under the National Academy of Sciences that regularly publishes sets of tables of each nutrient required by an animal for body maintenance, growth, production and rebreeding performance based on the latest available research.

**Near Infrared Reflectance Spectroscopy (NIRS) or Near Infrared Analysis (NIRA)**
The NIRS method of analysis is a computerized instrumental method for rapidly and reproducibly measuring the chemical composition of samples with little or no sample preparation other than drying and grinding. As opposed to conventional "wet chemistry" methods, NIRS measures the reflections of near infrared light instead of chemicals to determine protein, fiber, energy and other variables of interest. It is based on the fact that each of the major chemical components of a sample has characteristic near infrared light absorption (and hence reflectance) patterns, which are used to differentiate one component from the others. NIRS has been proved as a rapid and low-cost method for analyzing forage and grain crops for their nutritive value. Generally speaking, relative to conventional "wet chemistry" procedures, this method is much faster in determining forage nutritional content and is less expensive. It is very precise but the accuracy of NIRS is dependent on appropriate calibration with the results of "wet chemistry."

### Net Energy (NE)
Net energy refers to the amount of feed energy actually available for animal maintenance, growth and production. Conceptually, total NE is the portion of metabolizable energy (ME) remaining after the energy expended in body heat (or "heat increment of feeding") is deducted, (i.e., NE = ME - heat increment of feeding). NE is further partitioned into the net energy necessary for maintenance (no gain or loss of body weight), growth (or gain in body weight) and lactation (production of milk). The NE requirements for maintenance, growth and lactation are denoted by NEm, NEg, and NEl, respectively.

It should be kept in mind that most published NE values for feeds are not measured values; rather, they are estimated (or converted) from the DE system, so they are subject to the same set of limitations as an estimation of digestibility in the DE system. Nevertheless, the NE system is quite useful for ration formulation and evaluation.

### Net Energy for Gain or Growth (NEg)
NEg is an estimate of the energy in a feed used for body weight gain once maintenance is achieved.

### Net Energy for Lactation (NEl)
NEl is an estimate of the energy in a feed used for maintenance plus milk production during lactation.

### Net Energy for Maintenance (NEm)
NEm is an estimate of the energy in a feed used to keep an animal in energy equilibrium, neither gaining weight nor losing weight.

### Neutral Detergent Fiber (NDF)
NDF is the residue or insoluble fraction left after boiling a feed sample in neutral detergent solution. The NDF contains plant cell wall components except for some pectins. The NDF is considered a close estimate of the total fiber constituents of feedstuffs since it measures cellulose, hemicellulose, lignin, silica, tannins and cutins. The hemicellulose, cellulose and lignin represent the fibrous bulk of the forage. Because they give the plant rigidity and enable it to support itself as it grows, these three components are classified as structural carbohydrates. Though lignin is indigestible, hemicellulose and cellulose can be (in varying degrees) digested by microorganisms in animals with either a rumen (e.g., cattle, goats or sheep) or hind-gut fermentation (e.g., horses, rabbits, guinea pigs) as part of their digestive tract.

NDF concentration is negatively correlated with dry matter intake (i.e., as NDF in the forage increases, animals will consume less forage). As a result, NDF is often used in formulas to predict the dry matter intake.

### Neutral Detergent Fiber Digestibility (NDFD)
NDFD is the 48-hour in vitro digestible fraction of NDF expressed as percentage of the Neutral Detergent Fiber (NDF) content of a feed sample.

### Neutral Detergent Solubles (NDS)
The NDS represents all forms of ingredients in a feed sample that are soluble in neutral detergent solution. That means it represents everything that is not NDF. Usually 98 percent of the NDS is assumed to be digestible.

### Nitrate ($NO_3$)
Nitrate concentrations in forages and other feeds are generally low. When the rate of nitrate uptake (e.g., uptake per day) by the plant from the soil exceeds its rate of conversion to protein, nitrates will accumulate in plants. Nitrates can accumulate in the forage crop due to excessive nitrogen fertilization and excessive moisture stress or other factors that limit growth. Excessive concentrations of nitrate in the animal's diet can induce nitrate toxicosis in the animal (e.g., reduced weight gain, failure to rebreed, weakness, staggering and, in severe cases, death).

A qualitative check called the "diphenylamine test" can be used to screen forages for potential harm from nitrate. These types of test kits are available in most county Extension offices. The concentration of nitrate that is considered toxic varies considerably from one class of animal to another. More specific guidelines on preventing or mitigating nitrate toxicity in forages can be found in UGA Extension Circular 915, "Nitrate Toxicity."

The amounts of nitrate in the animal's water supply should also be considered. The University of Georgia recommends testing the nitrate content in the forage and water provided to your livestock if elevated levels of nitrate are suspected.

### Nitrogen-free Neutral Detergent Fiber (NDFn)

Nitrogen-free NDF (NDFn) is estimated as:

- NDFn = NDF – NDFICP (Neutral Detergent Fiber Insoluble Crude Protein)
- Also estimated as NDFn = NDF × 0.93.

### Non-fibrous Carbohydrate (NFC or Neutral Detergent Soluble Carbohydrates (NDSC)

NFC or NDSC represents all forms of digestible carbohydrates that are solubilized after boiling a feed sample in neutral detergent solution. These are all forms of non-cell-wall carbohydrates and include starch, sugar, pectin and fermentation acids, which are digestible and serve as energy sources for the animal. Because NFC includes some other digestible compounds in addition to starch and sugars included in NSC, NFC generally shows a higher value than non-structural carbohydrate (NSC) on the feed analysis report. NFC is calculated from the following equation:

NFC% = 100% – [CP% + (NDF% –NDFICP%) + EE% + Ash%]

Where EE% is the ether extract% or fat%.

### Non-protein Nitrogen (NPN)

NPN refers to nitrogen in a feed sample that is not in the form of protein but can be used by the microbial population in the rumen or gastro-intestinal tract to synthesize amino acids and proteins. Common forms of NPN are urea and ammonia.

### Non-structural Carbohydrate (NSC)

NSCs are simple carbohydrates, such as starches and sugars, stored inside the cell that can be rapidly and easily digested by the animal. Hence, NSC is considered to serve as a readily available energy source.

### Nutrient Requirements

Nutrient requirement refers to the minimum amounts of nutrients (energy, protein, fat, minerals and vitamins) necessary to meet an animal's real needs for maintenance, growth, reproduction, lactation or work (but does not include a safety margin in ration formulation).

### Nutritive Value (NV)

Nutritive value refers to a feed's protein, mineral and energy composition, availability of energy, and efficiency of energy utilization.

### Palatability

Palatability refers to the appeal and acceptability of feedstuffs to an animal. Palatability is affected by the feed's odor, texture, moisture, physical form and temperature. For a forage to be considered "high-quality," it generally must be highly palatable because quality includes intake and palatability is required for high levels of intake (see Dry Matter Intake).

Palatability is a plant trait that can be measured when the animal has the opportunity to selectively feed. However, when not given the opportunity to selectively feed the animal may perform just as well on the less palatable forage.

### Particle Size
Particle size refers to the diameter of granular feed materials (e.g., grains, pellets, mineral particles) and/or the length and sometimes width of roughage or forage fragments. Particle size can affect mixing of feed ingredients and digestion rate.

### Parts Per Million (ppm)
Parts per million is a unit of measurement used to state the concentration of specific nutrients, compounds or elements present in small quantities in a feedstuff (e.g., 1 ppm = milligrams per kilogram (mg/kg), 1 pound per million pounds, 1 milligram per liter (mg/L), or 1 microliter per liter (µL/L). Some more practical equivalents of 1 ppm are:

- 1 inch in 16 miles
- 1 second in 11 days and 16 hours
- 1 cent in $10,000
- 1 pinch of salt in 10 kg of potato chips
- 1 bad apple in 2,000 barrels

### pH
pH is a measure of acidity or alkalinity. Values range from 0 (most acidic) to 14 (most alkaline or basic). A pH value of 7.0 is neutral (neither acidic nor alkaline). The values give the negative log of the hydrogen ion concentration.

### Pectin
Pectin is an intercellular (occurs in between cells) polysaccharide (carbohydrate) that functions as a cellular glue. Like the nonstructural carbohydrates, it is easily degraded in the rumen. Unlike the NSCs, though, it does not lower rumen pH (i.e., acidic condition in the rumen).

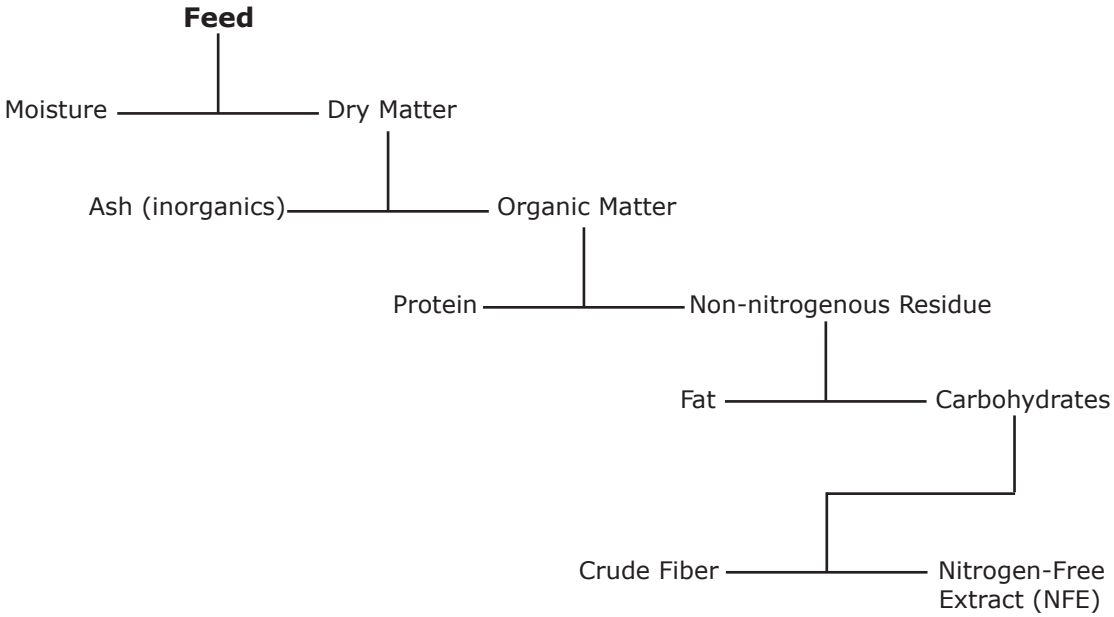
### Protein
Protein is an essential nutrient. Proteins are composed of long chains of various kinds of amino acids. Animals meet their protein needs by breaking down plant and microbial protein (formed in the rumen) and reassembling them as animal proteins.

### Proximate Analysis
Proximate analysis is a chemical method of quantitative analysis that separates, identifies and quantifies the major categories of compounds in a mixture. In feed and food analysis, it serves as a tool for assessing and expressing the broad nutritional value of a feed sample. The proximate system for routine analysis of animal feedstuffs was devised in the mid-nineteenth century at the Weende Experiment Station in Germany (Henneberg and Stohmann, 1860, 1864) and is referred to as the Weende System of proximate analysis (or simply, the Weende analysis).

It is important to remember that proximate analysis is not a nutrient analysis. Rather, it is a partitioning of both nutrients and non-nutrients into categories based on common chemical properties. The technique was developed to provide a top level, very broad classification of food components. The system consists of the consecutive steps of analytical separations and determinations of six categories of components and expressing the percentage of each that is present in a feed sample (Figure 2):

- Water/moisture (or dry matter)
- Ash (minerals)
- Total or crude protein (total nitrogen×6.25)
- Total or crude fat (or ether extract)
- Crude fiber (incompletely digested carbohydrates)
- Nitrogen-free extract (readily digestible carbohydrate)

**Figure 2.** A schematic that describes various components of feedstuffs usually partitioned in proximate analysis.




This system was developed at a time when the chemistry of most feed and food constituents was only partially understood, and the growth of nutritional sciences was at its earliest stages. Some of the methods used historically in the proximate system of analysis are no longer recommended for feed analysis (e.g., crude fiber). Nevertheless, the concepts formed the basis of modern feed analyses. Further, proximate analysis, including the original methodology, is still commonly used for food and feed regulations in many countries.

### Ration

Ration refers to the 24-hour feed allowance for an individual animal.

### Relative Feed Value (RFV)

Relative feed value is a forage quality term that is used to rank feeds, especially forages, according to their overall nutritive value. This ranking is made relative to the typical nutritive value of full bloom alfalfa hay. Full bloom alfalfa hay, containing 41 percent ADF and 53 percent NDF on a dry matter basis, has an RFV of 100 and is considered to provide the average score. Though RFV has no units, it compares the potential of two or more like forages on the basis of energy intake. Thus, it serves as an index of forage quality for comparing forage lots. For example, forages with RFV greater than 100 are of higher quality than full bloom alfalfa hay, and forages with a value lower than 100 are of lower value than full bloom alfalfa. Such a single suitable parameter is useful for practical forage pricing and marketing.

The RFV is calculated based on the two laboratory-determined parameters: NDF and ADF. NDF is used as an indicator of forage intake and ADF is used as an indicator of digestibility. Thus, together, ADF and NDF estimate intake potential and digestibility, and they are used to calculate RFV as:

- RFV = DDM (% of DM) × DMI (% of BW) ÷ 1.29

  Where, DDM (digestible dry matter) and DMI (dry matter intake) can be calculated from ADF and NDF as:
- DDM (% of DM) = 88.9 – 0.78 × ADF (% of DM)
- DMI (% of BW) = 120 ÷ NDF (% of DM)

Due to the inherent variability of measuring ADF and NDF, absolute RFV numbers are not recommended for making direct comparisons or pricing of forages. Rather, a range of RFV values (±5 points of the target) is a more reasonable way to classify a forage (e.g., if an RFV of 140 is desired, any forage with an RFV of 135 to 145 should be considered to have an equivalent value).

One of the limitations of the RFV system is that it assumes constant relationships between NDF and intake, and between ADF and digestibility. However, two forages can have identical NDF levels but very different digestibilities and, therefore, intakes. This often results in the RFV of high-quality forages being underestimated because their intake is underestimated.

### Relative Forage Quality (RFQ)

RFQ is a forage quality term that is similar to RFV in that it is used to rank forages according to their relative nutritive value. RFQ shares many of the properties of RFV (e.g., its basis of comparison is 100, the typical nutritive value of full bloom alfalfa hay; it has no units; it compares the potential of two or more like forages on the basis of energy intake; it serves as a useful index of forage quality for comparing forage lots; and it is very useful for practical pricing and marketing of forage lots). Unlike RFV, however, RFQ takes into account digestible fiber (Moore and Undersander, 2002a, 2002b).

RFQ is based on intake and true TDN instead of DDM. This makes RFQ a better predictor of forage quality than RFV. This is because RFQ accounts for NDF digestibility (NDFD) and the contribution of other nutrient fractions when calculating TDN, rather than calculating DDM based merely on ADF. RFQ is calculated as:

- RFQ = DMI (% of BW) × (TDN (% of DM) ÷ 1.23

The above equation for RFQ includes the adjustment factor 1.23, which allows the RFQ to retain the value of 100 for full bloom alfalfa (similar to RFV), which serves as the base value.

The equations used to calculate DMI and TDN for legumes and legume/grass mixtures are specific to those forages and are different from those used to calculate DMI and TDN for warm and cool season grasses. Proper identification of forage type will therefore be essential before RFQ calculation. The two recommended equations for DMI and TDN calculations depend on whether or not the primary forage is legume or grass and are explained in the definition of "Dry Matter Intake" and "Total Digestible Nutrients" in this publication. For more information on RFQ, visit the RFQ information page on the UGA Forages website (*www.georgiaforages.com*).

### Roughage

Roughage refers to bulky and coarse feed high in fiber (greater than 18 percent crude fiber) but lower in energy than most concentrates. For example, forage, hay, silage and haylage are sometimes called roughage.

### Rumen

The rumen is the foregut (or forestomach) of ruminant animals such as cattle, sheep and goats. The rumen is a large, hollow muscular organ that is the site of most of the fiber digestion that occurs in ruminant animals. This digestion is largely performed by microorganisms (bacteria, protozoa and fungi) that inhabit the rumen.

### Ruminal Microbes

Ruminal microbes include the whole community of microorganisms present in the rumen of ruminant animals. They accomplish the digestion or fermentation of feed. An estimated 150 billion microorganisms per teaspoon are present in the contents of the rumen. This microbial community consists of bacteria, protozoa and fungi.

**Ruminants**
Ruminants are a class of animals that have multiple organs working together to accomplish digestion. The digestive tract consists of the reticulum (involved in rumination and in passage from the rumen to the omasum), rumen (large compartment used for fermentation), omasum (once called the manyplies, it removes excess liquid and nutrients moving out of the reticulo-omasal orifice), and abomasum (acid-pepsin digestion similar to a monogastric). By comparison, monogastric animals (e.g., swine and humans) have a simple or single-chambered stomach that utilizes an acid-pepsin digestion to extract nutrition from the ingested food.

**Rumen Degradable Protein (RDP)**
RDP is also known as Degradable Intake Protein (DIP). See DIP for more detail.

**Rumen Undegradable Protein (RUP)**
RUP is another name of by-pass protein, escape protein or undegradable intake protein (UIP). See By-pass Protein for more detail.

**Saccharides**
Saccharides is another name for simple sugars or polymerized sugar. See Carbohydrate for more detail.

**Silage**
Silage refers to the feed preserved by an anaerobic fermentation process (e.g., corn silage, haylage, high moisture corn) in which lactic acid and volatile fatty acids (produced by fermentation) lower the pH of the silage. The low pH preserves the silage. See Ensiled.

**Silage Additives**
Silage additives refer to the substances added during the ensiling process to enhance production of lactic acid and/or a rapid decrease in pH of the feed.

**Soluble Intake Protein (SIP)**
SIP includes the non-protein nitrogen and that portion of true proteins that are readily degraded to ammonia in the rumen. They are used to synthesize microbial protein in the rumen.

**Starch**
Starch is an intracellular (occurs within the cells) carbohydrate found primarily in the grain or seed and/or root portions of plants. Starch is a readily available source of energy.

**Structural Carbohydrates**
Structural carbohydrates are the complex carbohydrates that form the plant cell wall and include cellulose, hemicellulose, lignin and pectin. They are typically measured in the laboratory as neutral detergent fiber (NDF).

**Supplement**
A supplement feed or feed mixture is used to improve the nutritional value of the ration complementing the nutrients in the base feed. A supplement is rich in one or more of protein, energy, vitamins or minerals, and, in combination with the base feeds, produces a more complete feed.

**Total Digestible Nutrients (TDN)**
TDN is a measure of the energy value in a feedstuff. The term TDN has its origins in an older system of measuring available energy in feeds and is very hard to measure directly. Today, reported TDN values are calculated, not measured values. Formulas for calculating TDN originally were based on ADF and frequently varied by region and the nutritionist doing the calculation.

The National Research Council (NRC) suggested a more accurate and robust procedure of estimating TDN than those based solely on ADF (NRC, 2001). Their procedure is based on the assumption that forage classes (legumes, cool season grasses, warm season grasses, etc.) have more uniform and predictable digestion coefficients. So, they proposed that the TDN for alfalfa, clovers and legume/grass mixtures be calculated as follows:

- $TDN_{legume}$ = (CP × 0.93) + (FA × 0.97× 2.25) + [NDFn × (NDFD ÷ 100)] + (NFC × 0.98) – 7
  Where:
  NDFn = nitrogen free NDF = NDF – NDFICP, also estimated as NDFn = NDF × 0.93
  NDFICP = neutral detergent fiber insoluble crude protein
  NDFD = 48-hour in vitro NDF digestibility (% of NDF)
  NFC = non fibrous carbohydrate (% of DM) = 100 – (NDFn + CP + EE + ash)
  EE = ether extract (% of DM)

The TDN for warm and cool season grasses is calculated as:

- $TDN_{grass}$ = (NFC × 0.98) + (CP × 0.87) + (FA × 0.97 × 2.25) + [NDFn × (NDFDp ÷ 100)] – 10
  Where all other terms are as defined previously and NDFDp = 22.7 + 0.664 × NDFD

Though TDN is a widely used measure of energy, it is not without its weaknesses. The most significant issue with TDN is that it does not account for additional energy losses, particularly heat increment and, to some extent, gaseous losses, especially regarding ruminant systems. Consequently, TDN is known to over-estimate the energy value of roughages compared to grains.

### Total Mixed Ration (TMR)
A total mixed ration is a homogenous mixture of mechanically mixed ration ingredients that typically combine roughages (forages) and concentrates such as grains to optimize animal performance. TMRs are commonly used in large dairy or beef feedlot operations.

### Toxicity
Toxicity refers to the extent to which a substance can exert a poisonous effect on animals.

### Undegradable Intake Protein (UIP)
UIP is sometimes used as another name for by-pass protein, escape protein or Rumen Undegradable Protein (RUP). The use of UIP is sometimes a misnomer since it generally refers to material that is not degraded in the rumen but is degraded in the abomasum and thus is not truly "undegradable." See By-pass Protein for more detail.

### Vitamins
Vitamins are organic compounds that typically function as parts of enzyme systems essential for many metabolic functions.

### Water-soluble Carbohydrates (WSC)
WSCs are the carbohydrates that can be solubilized and extracted in water. WSCs include monosaccharies, disaccharides and some short chain polysaccharides, mainly fructans, which are a major storage carbohydrate in some cool season grasses (e.g., timothy).

## "Wet Chemistry" Analysis

Wet chemistry is a term that collectively refers to a number of scientific techniques involving direct analyses with solvents, acidic or basic solutions, other chemicals and other traditional laboratory methods used to analyze feed samples (e.g., various drying and burning procedures). The procedures are based on sound chemical and biochemical principles, but require the sample to be destroyed and take considerably more time to complete than the newer methods, such as Near Infrared Spectroscopy (NIRS). Still, wet chemistry is the basis for all modern, instrument-based, analytical methods and for calibration of NIRS methods. Wet chemistry methods are the most accurate methods for determining nutrient values of feeds/forages and are frequently used for quality assurance purposes or in the development of new techniques/calculations.

## References


CAST (Council for Agricultural Science and Technology). 1989. Mycotoxins: Economic and health risks. Task Force Report No. 116. Ames, Iowa.

CAST (Council for Agricultural Science and Technology). 2003. Mycotoxins: Risks in plant, animal and human systems". Task Force Report No. 139. Ames, Iowa.

Henneberg, W. and F. Stohmann. 1860. Beiträge zur Begründung einer rationellen Fütterung der Wiederkäuer, Vol. I. Schwetsehtke u. Sohn, Braunschweig, p. 4.

Henneberg, W. and F. Stohmann. 1864. Beiträge zur Begründung einer rationellen Fütterung der Wiederkäuer, Vol. II. Schwetsehtke u. Sohn, Braunschweig, p. 324.

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64:1548-1558.

Moore, J.E. and D. J. Undersander. 2002a. Relative forage quality: A proposal for replacement for Relative Feed Value. 2002 Proceedings National Forage Testing Association.

Moore, J. E. and D. J. Undersander, 2002b. Relative forage quality: An alternative to relative feed value and quality index. p. 16-31 In: Proc. Florida Ruminant Nutrition Symposium, January 10-11, University of Florida, Gainesville.

Moore, J.E., and W.E. Kunkle. 1999. Evaluation of equations for estimating voluntary intake of forages and forage-based diets. J. Animal Sci. (Suppl. 1):204.

Nakamura, T., T.J. Klopfenstein and R.A. Britton. 1994. Evaluation of acid detergent insoluble nitrogen as an indicator of protein quality in nonforage proteins. J. Animal Sci. 72:1043-1048.

NRC (National Research Council). 2001. Nutrient requirements of dairy cattle. 7th rev. ed. Natl. Acad. Sci., Washington D.C. 381p.

Oba, M. and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Van Soest P. J. 1963a. Use of detergents in the analysis of fibrous feeds. I. Preparation of fiber residues of low nitrogen content. J. Assoc. Off. Anal. Chem. 46:825-829.

Van Soest P. J. 1963b. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Anal. Chem. 46:829-835.

Van Soest, P.J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583-3597.