Fundamentals of Ration Balancing for Beef Cattle Part II: Nutrient Terminology

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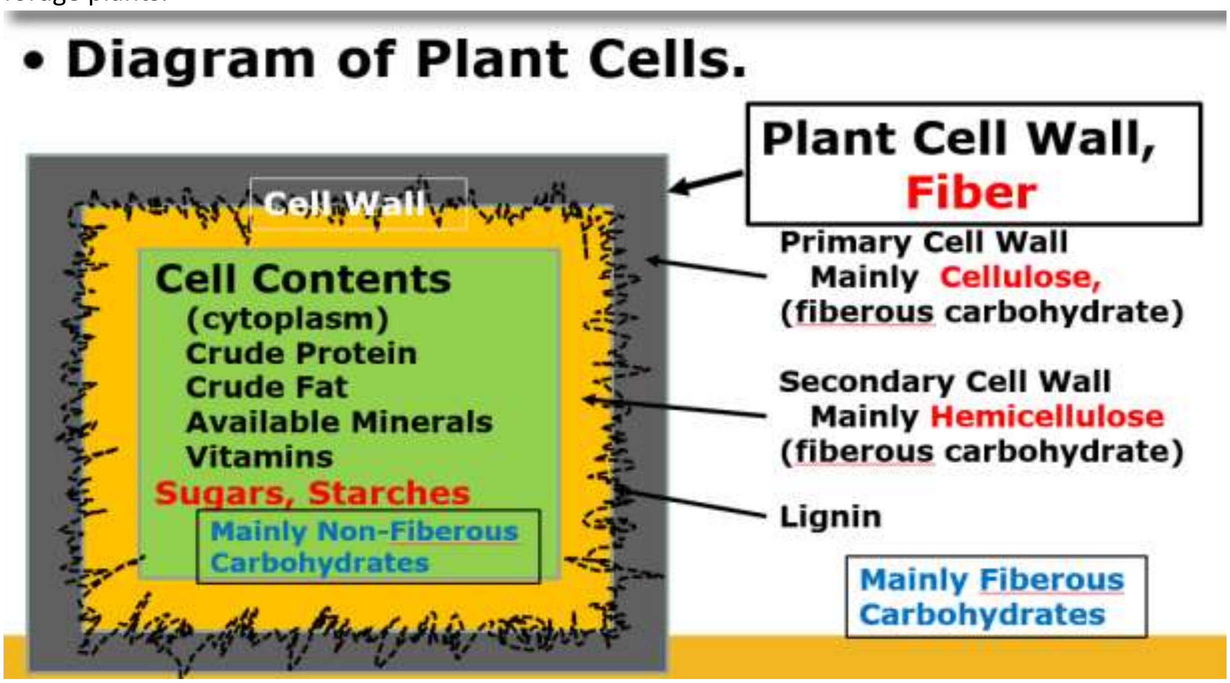
What information and skills are required to balance diet for beef cattle?

1. The nutrient content of the feeds available, as well as the cost or value of those feeds.
2. The nutrient requirements of beef cattle based on production expectations and some knowledge regarding nutrient balance, overloads and toxicities.
3. PPPHC: piece of paper, pencil, and a hand calculator.
4. Arithmetic skills.

In Part I of this series of articles, the concept of **As-Fed/Dry Matter Basis** was explained . In this article (Part II), basic **Nutrient Terminology** is reviewed with the objective of **understanding a laboratory nutrient analysis report**. The following diagrams shows the location of the major nutrients in the cells of forage plants:



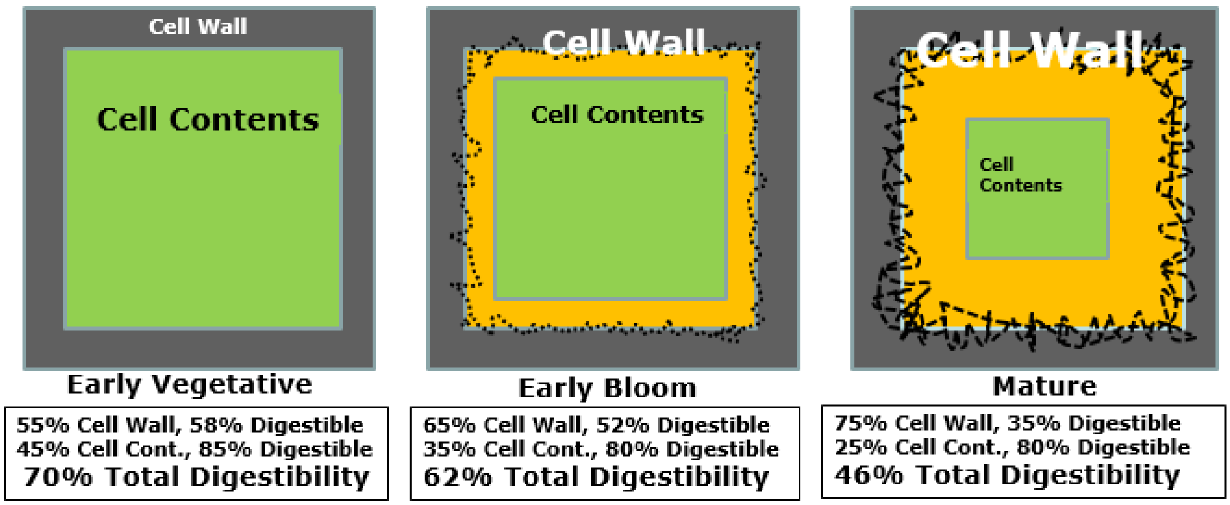
The six major nutrient groups are: **Water, Carbohydrates, Proteins, Lipids (fats), Minerals, and Vitamins.** The following table contrasts the body nutrient composition of a typical beef cow with her nutrient intake from 27.0 lbs. of dry matter (DM) of good-quality forage and free-choice drinking water:

Nutrient	Body Composition, %	Typical Nutrient Intake, Good Quality Hay, lbs./day
Water	62.0	125.0 (82.24%)
Carbohydrate	1.0	20.8 (13.68%)
Protein	16.0	3.2 (2.11%)
Lipid (fats)	16.0	.8 (.53%)
Mineral	4.5	2.1 (1.38%)
Vitamins	.5	.1 (.06%)

Obviously, nutrient transformations associated with the cows' metabolism have taken place. Water is consistently of the highest proportion in both the diet and the body composition of the cow. However, there have been major changes in the ratios of carbohydrates, proteins, and lipids regarding the diet compared to the cow's body composition. Carbohydrates have been used and/or transformed in the processes of animal metabolism.

The following diagram depicts the changes in cell structure and animal nutrient utilization associated with the advancing maturity of forage plants:

- **Diagrams of Forage Plant Cells With Advancing Maturity:**



Since **Carbohydrates (CH_2O)** are usually the nutrients of the highest concentration in most beef cow diets, the following are a few comments describing carbohydrates:

1. Carbohydrate (glucose) is the product of the **"Miracle of Photosynthesis"** in plant tissues.
2. Carbohydrates are the major **Energy Source** for most farm animals.
3. **Supplying Energy** accounts for **80% of the cost** of feeding farm animals.
4. Carbohydrates can be segregated into many different biochemical categories, but with regard to farm animal nutrition, **Fiberous Carbohydrate versus Non-Fiberous Carbohydrate** is of most importance.
5. **Fiberous Carbohydrates are the most abundant organic molecules on Earth**.
6. The term used to describe the Fiberous Carbohydrate content in farm animal feeds is **Neutral Detergent Fiber or NDF**. The term **"cell wall" and NDF** are often used synonymously. **Acid Detergent Fiber or ADF** is a component of NDF. **NDF and ADF are usually used in tandem to estimate forage intake and digestibility**.

- **ADF is a Partial Cell Wall.**

7. The term **Fiber** usually implies that these carbohydrates can be utilized in animals **only** by digestive enzymes produced by **Microorganisms** inhabiting the gastro-intestinal tract. So herbivores such as ruminants (cattle, sheep, goats) that have specialized gastro-intestinal tracts to house large numbers of these microorganisms can make relatively efficient use of NDF.
8. There is an Inverse Relationship between the NDF/ADF content of animals feeds and feed intake and energy content: **the Higher the NDF/ADF Content, the Lower the Intake and Energy Content (Intake x Energy content = Energy Intake)** . The Energy Content of farm animal feeds can be described using several different terms (Metabolizable Energy, Net Energy), but **Total Digestible Nutrients or TDN** remains in extensive use. The table below illustrates this relationship between the NDF (fiber) content of forages, the intake of those forages, the available energy content of those forages, and thus energy intake:

Nutrient	Pre-Bloom Hay	Early Bloom Hay	Mature Hay
NDF, % of DM	**55.0**	**64.0**	**75.0**
TDN, % of DM	**62.0**	**56.0**	**45.0**
Intake, % of Body WT	**2.2**	**1.9**	**1.6**
Intake, 1200 lb. Cow, lbs. DM/day	**26.4**	**22.8**	**19.2**
Energy Intake 1200 lb. Cow, lbs. TDN/day	**26.4 x .62 = 16.4**	**22.8 x .56 = 12.8**	**19.2 x .45 = 8.6**

Next to Energy, **Protein (CHON)** is the second most costly nutrient. Unlike most carbohydrates, proteins contain **Nitrogen**. High-Quality Proteins are the major products of animal agriculture, i.e., meat, milk, eggs, wool, leather. The following are a few comments describing dietary protein:

1. As with Energy, the Protein Requirement of farm animals and the protein content of animal feeds can be expressed or described in several ways (metabolizable protein, amino acids). For most herbivores the term **Crude Protein (CP)** remains in common use. As the name implies, CP is a "crude" estimate of the protein content of animal feeds based on the **nitrogen content** of those feeds. The assumptions of the concept of crude protein are that most of the nitrogen in animal feeds is associated with proteins and that most proteins contain about 16% nitrogen. Those assumption can be risky in some situations, but for the most commonly used animal feed are reasonably accurate. Thus (100÷16) **6.25 x % Nitrogen of a feed = Crude Protein**.
2. Some feed analysis laboratories include both CP and Nitrogen in their reports. Remember that 6.25 x % Nitrogen = %CP.
3. With forages of a **given type**, there is usually an Inverse Relationship between CP content and NDF content and thus a positive correlation between CP content and TDN (energy) content. The following table depicts these concepts:

Nutrient	Pre-Bloom Hay	Early-Bloom Hay	Mature Hay
CP, % of DM	**15.0**	**10.0**	**6.0**
NDF, % of DM	**55.0**	**64.0**	**75.0**
TDN, % of DM	**62.0**	**56.0**	**45.0**

However, this is not the case with forages of **different types** or with **commodity feeds** as illustrated in the tables below:

Nutrient	Alfalfa Hay, Early Bloom	Grass Hay, Early Bloom
CP, % of DM	22.0	11.0
NDF, % of DM	47.0	61.0
TDN, %of DM	58.0	59.0

Nutrient	Corn Grain	Corn DDG	Soybean Hulls
CP, % of DM	9.8	29.5	12.2
NDF, % of DM	9.0	46.0	66.3
TDN, % of DM	88.0	88.0	80.0

4. Some laboratory reports will also include **Available CP**. If the Available CP is lower than the Total CP, there has likely been **Heat Damage** to the feed either from internal heating (wet stored hay) or high processing temperatures in commodity feeds. When feeds reach high temperatures (250 to 300˚F) for a long enough period of time, reactions (Maillard) take place between certain proteins and carbohydrates. The resultant compounds are similar to components of Acid Detergent Fiber (ADF) except for higher than normal nitrogen content. Laboratories will analyze ADF of feeds for nitrogen content (ADF-N or ADF-CP) and if too high **(greater than 10% of total CP),** the Total CP will be proportionately reduced and Available CP calculated, as depicted in the following table:

Nutrient Item	Hay 1	Hay 2
Total Nitrogen, % of DM	1.85	1.98
Total CP, % 0f DM	(1.85 x 6.25) **11.56**	(1.98 x 6.25) **12.38**
ADF-N (nitrogen), % of DM	.064	.329
ADF-CP, % of DM,	(.064 x 6.25) .400	(.304 x 6.25) 2.056
ADF-CP, % of Total CP	(.400 ÷ 11.56) x 100) 1.460	(2.056 ÷12.38) x 100)16.61
Total CP Adjustment Needed?	ADF-CP < 10% of Total CP NO	ADF-CP > 10% of Total CP YES
Total CP Adjustment Factor	None	(100- (16.61 – 10) ÷ 100 = .9339
Available CP, % of DM	**11.56**	12.38 x .9339 = **11.56**

Note that although the total CP of these forages differ, due to heat damage to the CP in Hay 2, the Available CP of the two hays is equivalent.

The next major nutrient group is **Lipids (fats and oils) (CHO).** The following are a few comments describing lipids in animal feeds:

1. The significance of the lipid content of animal feeds is that lipids usually contain about **2.25 Times the Energy** of carbohydrates. Feeds that have high lipid content are generally high in energy.
2. Most laboratories will report the lipid content of animal feeds as either **Crude Fat (CFat) or Ether Extract (EE),** which are synonymous. The “crude” in crude fat implies that it is a crude estimate of the lipid content of animal feeds. CFat or EE includes all of the compounds in a feed that are extracted with diethyl ether, some of which can be **non-nutritive**. Some forage plants and other feeds can contain high concentrations **waxes** that are a portion of the CFat but are of very low digestibility. Some forbs and weeds can be as high as 30% CFat, most of which are non-nutritive lipids or even anti-nutritional. However, with most commonly used animal feeds CFat or EE are reasonably good estimates of **nutritive lipid content**.

3. Most forages contain between 2 and 4% of DM as Crude Fat. However, commodity feeds are quite variable in CF content, between 2 and 20% of DM, as shown in the following table:

Nutrient	Pre Bloom Hay	Mature Hay	Corn Grain	Corn DDG	Whole Cottonseed
CP, % of DM	15.0	6.0	9.8	29.5	24.4
NDF, % of DM	55.0	75.0	9.0	46.0	51.6
CFat, % of DM	3.0	2.0	4.3	10.3	17.5
TDN, % of DM	62.0	45.0	88.0	88.0	90.0

The total **Mineral Content** of animal feeds is generally determined by combusting a sample at about 950˚F. All of the organic materials (NDF, CP, CFat, and vitamins) are completely oxidized, leaving the mineral materials, which have been designated as **Ash**. Thus ash is the sum total of all of the minerals in animal feeds. The following are few comments regarding the Ash or Mineral components of animal feeds:

1. The ash content of feeds is of limited value in balancing diets for farm animals. However, very high ash content can imply low feed energy content because minerals do not directly supply energy to animals. Extraordinarily high ash content can also indicate contamination with soil, etc.
2. Analyzing feeds **for individual mineral concentrations** is necessary for proper diet balancing.
3. The ash content of feeds commonly used to feed farm animals can vary greatly as illustrated in the following table:

Nutrient	Grass Hay	Corn Grain	Corn DDG	Dical Phosphate
CP, % of DM	10.0	9.8	29.5	0
NDF, % of DM	64.0	9.0	46.0	0
CFat, % of DM	2.0	4.3	10.3	0
TDN, % of DM	56.0	88.0	88.0	0
Ash, % of DM	9.0	1.6	5.2	100

Non-Fiberous Carbohydrates (NFC) represent the highly digestible carbohydrates in animal feeds such **Sugars and Starches**. This group of carbohydrates is generally determined by "difference" rather than a direct chemical analysis. Using the **grass hay** in the table above as an example, **the NFC is calculated as all nutrients not accounted by CP, NDF, CFat, and Ash**: 100 – (10.0 + 64.0 + 2.0 + 9.0) = **15% NFC.** By contrast, the NFC content of the corn grain in the table above is calculated as follows: 100 – (9.8 + 9.0 + 4.3 + 1.6) = **73.5% NFC**. Hay and pastures high in NFC can increase the incidence of **founder** in some horses. The table below shows the feeds in the table above but with NFC calculated:

Nutrient	Grass Hay	Corn Grain	Corn DDG	Dical Phosphate
CP, % of DM	10.0	9.8	29.5	0
NDF, % of DM	64.0	9.0	46.0	0
CFat, % of DM	2.0	4.3	10.3	0
TDN, % of DM	56.0	88.0	88.0	0
Ash, % of DM	9.0	1.6	5.2	100
NFC, % of DM	15.0	75.3	9.0	0

The **Nutrient Terminology** described above is the basis of the original **Proximate Analysis** that was developed at the Weende Agricultural Experiment Station in Hanover Germany in the 1850s. With minor adjustments it remains in use today. The following is an example of a laboratory forage analysis along with explanatory calculations:

Tall Fescue Hay:

Nutrient	Calculation	As-Fed Basis	Calculation	Dry Matter Basis
Moisture (Water), %	100 - 84.63 =	15.37		0
Dry Matter, %	100 -15.37 =	84.63		100.00
Nitrogen, %		1.2629	1.2629 ÷ .8463 =	1.4923
Crude Protein, %	1.2629 x 6.25 =	7.89	7.89 ÷ .8463 =	9.33
Acid Detergent Fiber-Nitrogen, %		.0906	.0906 ÷ .8463 =	.107
Acid Detergent Fiber-Crude Protein, %	.0906 x 6.25 =	.566	.566 ÷ .8463 =	.669
ADF-CP, % of Total CP	.556÷7.89 (x100)=	7.17 (< 10%,OK	No Heat Damage	
Available Crude Protein, %		7.89	7.89 ÷ .8463 =	9.33
Acid Detergent Fiber(ADF), %		35.96	35.96 ÷ .8463 =	42.49
Neutral Detergent Fiber(NDF), %		54.50	54.50 ÷ .8463 =	64.40
Crude Fat (Ether Extract), %		1.77	1.77 ÷ .8463 =	2.09
Ash, %		6.01	6.01 ÷ .8483 =	7.10
Non-Fiberous Carbohydrate(NFC), %	100-(15.37+7.89+54.50+1.77+6.01) =	14.45	100-(9.33+64.40+2.09+7.10) =	17.08
Total Digestible Nutrients, %	53.98 x .8463 =	45.69	92.62-(.9093x42.49) =	53.98
Calcium, %		.305	.305 ÷ .8463 =	.360
Phosphorus, %		.1379	.1379 ÷ .8463 =	.163
Magnesium, %		.2877	.2877 ÷ .8463 =	.340
Potassium, %		1.117	1.117 ÷ .8463 =	1.32
Sodium, %		.0084	.0084 ÷.8463 =	.0099
Sulfur, %		.1464	.1464 ÷ .8463 =	.1730
Iron, ppm		135.40	135.40 ÷ .8463 =	159.99
Copper, ppm		4.23	4.23 ÷ .8463 =	5.00
Manganese, ppm		44.85	44.85 ÷ .8463 =	53.00
Zinc, ppm		31.31	31.31 ÷ .8463 =	37.00

There are many **different equations** that have been developed to **estimate the TDN (energy) content of animal feeds**. Many of these equations are regionalized and are based on thousands of feed analyses in a particular geographic area. The equation used in this example **(92.62 – (.9093 x ADF, % of DM)** is based on the Acid Detergent Fiber content of the hay. Some equations are quite sophisticated and include crude protein, neutral detergent fiber, crude fat, ash, and non-fiberous carbohydrates as variables. The following is a TDN equation developed by Dr. Bill Weiss, Ohio State University:

$$.98 \times (100-NDFn-CP-Ash-EE)+e^{-.012 \times ADF-N} \times CP+2.25 \times (EE-1)+.75 \times (NDFn-Lig) \times (1-(Lig \div NDF^{.667}) - 7$$