2) COMPOSITION AND ANALYSIS OF FEEDS

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INTRODUCTION

Feeds contain nutrients that are used to meet the requirements of animals. Most feeds for dairy cows consist of the stems, leaves, seeds and roots of various plants. Cows can also be fed industrial by-products (oilseed meals, molasses, brewers grain, milling by-products, etc.) and their rations often need to be supplemented with small amounts of minerals and vitamins. Feeds for dairy cows are commonly classified as:

- Forage;
- Concentrate;
- Protein supplements;
- Vitamin and mineral supplements.

Although somewhat arbitrary, this classification is based on the value of a feed to supply a particular nutrient. *Nutrients* are chemical substances that are necessary for the maintenance, growth, production, reproduction and health of the animal. There are five categories of nutrients:

- Water;
- Energy (carbohydrates, proteins, lipids);
- Protein (nitrogenous compounds);
- Minerals;
- Vitamins.

Feeds may also contain substances that have no nutritive value (Figure 1). Some compounds have complex structures that are indigestible and may interfere with the digestion of some nutrients (e.g., lignin, tannins). In addition, certain plants and spoiled feeds contain toxins that are detrimental to the animal's health.

THE COMPOSITION OF FEED

Water and dry matter

When a feed sample is placed in an oven maintained at 105°C for 24 hours, the water (H₂O) evaporates and the residual dry feed is called *dry matter*. Feeds contain variable amounts of water. At immature stages of growth, most plants contain 70 to 80% water (i.e., 20 to 30% dry matter). However, seeds do not contain more than 8 to 10% water (i.e., 90 to 92% dry matter). The amount of water in the feeds is usually of little concern. Milking cows drink from 4 to 5 kg of water for each kg of dry matter they eat. Cows need access to fresh, clean water most of the day.

The dry matter contains all the nutrients (except water) required by the cows. The concentration of nutrients in a feed is commonly expressed on the basis of the amount of dry matter (DM) as opposed to the amount of fresh feed (as-fed) because:

- The amount of water is variable and thus, the nutritive value of different feeds is more easily compared when nutrient concentration is expressed on a dry matter basis.
- When expressed on a dry matter basis, the concentration of a nutrient in a feed can be compared directly to the concentration of that nutrient required in the diet of the cow.

Organic matter and minerals

The dry matter of a feed may be divided into organic matter and inorganic matter.
Compounds that contain carbon (C), hydrogen (H), oxygen (O) and nitrogen (N), are classified as organic. The inorganic compounds or minerals are the other chemical elements (calcium, phosphorus etc.). When a feed sample is placed in a furnace maintained at about 550°C for 24 hours, the organic matter is combusted (i.e., burned) and the residual matter is the mineral part of the feed also referred to as ash. In plants, the mineral content ranges from less than 1% to about 12%. Forages usually contain more minerals than seeds or grains. Animal by-products containing bones may contain as much as 30% minerals (primarily calcium and phosphorus). Minerals are often classified as macro- or micro-minerals (Table 1). This distinction is based only on the amount required by the animals. Some minerals are possibly essential (e.g., barium, bromine, nickel) and others are known to have a negative effect on digestibility of the feed (e.g., silica).

**Nitrogen-containing nutrients**

Nitrogen is present in proteins and other compounds included in the organic matter of a feed. Proteins are composed of one or several long chains of amino acids. The sequence of the 20 amino acids found in proteins is determined by the genetic code. This sequence determines the structure and the function of each protein in the body. Some amino acids are essential and others are non-essential. As opposed to the non-essential amino acids which can be synthesized within the body, the essential amino acids must be present in the diet because the body cannot synthesize them.

When nitrogen is not part of a protein structure such as in ammonia or urea, it is referred to as non-protein nitrogen (NPN). Non-protein nitrogen has no nutritive value in simple stomach animals. However, in ruminants, NPN can be utilized by ruminal bacteria to synthesize amino acids and proteins that will benefit the cow.

A Danish chemist, J.G. Kjeldhal, developed a method in 1883 to quantify nitrogen. On the average, proteins contain 16% nitrogen. Thus, the percentage of protein in a feed is usually calculated as the percentage of nitrogen multiplied by 6.25 (100/16 = 6.25). This measurement is referred to as crude protein (CP). The word "crude" refers to the fact that not all nitrogen in the feed is in the form of protein. Often, crude protein overestimates the percentage of "true" protein in a feed. The percentage of crude protein in forages ranges from less than 5% (crop residues) to more than 20% (good quality legumes). Oilseed meals may contain from 30 to 50% crude protein and animal by-products more than 60%.

**Energy-containing nutrients**

The energy of a feed that is available to the animal cannot be quantified by simple laboratory analysis. Rather, it is best measured by experimentation. In the body, the carbon (C), hydrogen (H) and oxygen (O) of carbohydrates, lipids and proteins can be converted to water (H₂O) and carbon dioxide (CO₂) with release of energy. The Megacalorie (Mcal) is commonly used as a unit of energy, but the Joule (J) is the official unit of measurement. In feeds for dairy cows, energy is expressed as Mcal of Net Energy of Lactation (NE₅).
This unit represents the amount of energy in a feed which is available for maintenance of body weight and milk production. For example, it takes 0.74 Mcal NE\(_1\) to produce 1 kg of milk and the energy in feeds ranges from 0.9 to 2.2 Mcal of NE\(_1\)/kg dry matter. Lipids and other fat-like substances are quantified by a method called *ether extract*.
(EE) and they usually yield 2.25 times the energy of carbohydrates. However, most of the energy in forages and many concentrates comes primarily from carbohydrates. Feeds for cows usually contain less than 5% lipids but 50 to 80% carbohydrates. There are three major classes of carbohydrates in plants:

- Simple sugars (glucose, fructose);
- Storage carbohydrates (starch) also referred to as non-structural, non-fibrous, or non cell wall carbohydrates;
- Structural carbohydrates also referred to as fibrous or cell wall carbohydrates (cellulose and hemicellulose).

Glucose is found in high concentration in some feeds (molasses, milk whey). Starch is the major component of cereal grains (wheat, barley, corn also called maize, etc.). Cellulose and hemicellulose are found primarily in the stem of plants. Starch and cellulose are made of long chains of glucose units. The bond between two glucose units can be broken down easily in starch, but in cellulose the bond resists the attack of digestive enzymes of higher animals. However, ruminal bacteria possess the enzymes to extract glucose units from cellulose and hemicellulose.

Cellulose and hemicellulose are associated with lignin (a phenolic compound) in the cell wall. The amount of fiber (i.e., cell wall) in a feed has important effects on its nutritive value. In general, the lower the fiber content, the higher the energy value of a forage. Fiber in the form of long particles is needed in the ration of cows because:

- It stimulates rumination, which is essential to maintain digestion and the health of the cow;
- It is essential to avoid a depression in the percentage of fat in the milk.

In many countries, crude fiber is still the official method to measure the fiber content of a feed, but neutral detergent fiber (NDF) is a more recent laboratory procedure that estimates accurately the amount of cellulose, hemicellulose and lignin in a feed. The potential intake of a forage by a cow is inversely related to its NDF content. In addition, the acid detergent fiber (ADF) which quantifies cellulose and lignin, is a good estimate of the digestibility of a forage. The sugars in the NDF or ADF are fermented slowly by ruminal bacteria, but the non-cell wall material (soluble cell content such as simple sugars, and some proteins), usually are readily fermented.

The percentage of non-fibrous carbohydrates (NFC) in a feed is usually calculated assuming that all that is not ash, crude protein, ether extract, and NDF is NFC:

$$\text{NFC} = 100 - (\text{ash} + \text{CP} + \text{EE} + \text{NDF}).$$

**Vitamins**

The vitamin content of a feed is not routinely determined, but vitamins are essential in small amounts to maintain health. Vitamins are classified as water soluble (nine vitamins of the B-complex and vitamin C) and fat soluble (β-carotene or provitamin A, vitamins D₂, D₃, E and K). In cows, B-complex vitamins usually are not required because ruminal bacteria can synthesize them.