# Basics of Ruminant Digestion

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Digestion occurs when complex materials found in feed are broken down into small fragments that can be absorbed into an animal's system and then used for growth, maintenance, reproduction and other functions. In ruminants (cows, sheep, goats, deer, etc.) digestion begins when food passes through the mouth, where it is chewed to break up the fibers. The food passes on to the **rumen** and **reticulum** – often considered one large organ called the **reticulo-rumen** – where **microbial digestion** (or fermentation) takes place. **M**icro-**o**rganisms (**MO**s) in the rumen and reticulum, such as bacteria and fungi, work to further break down the food. Specifically, they break down the carbohydrates in the diet and manufacture protein to meet the energy and nitrogen needs of the animal. The animal can regurgitate very fibrous material (the 'cud') from the rumen for more chewing. After leaving the reticulo-rumen, the partially digested food (digesta) enters the **omasum**, where water is absorbed. The rumen, reticulum and omasum constitute the **foregut**, which is the distinguishing feature of ruminants. The digesta then passes on to the **hindgut**, which includes the **abomasum**, or 'true' stomach, and the **intestines**. Here the digestive processes are the same as those that occur in other mammals – essentially the enzymatic (rather than microbial) breakdown of the digesta and absorption by the animal of the nutrients.

It is the distinctive processes that occur in the rumen that we are primarily concerned with in this article.

## Energy Requirements in Ruminants

**Energy** can be defined as **the capacity of a body to do work**. Plants get their energy directly from sunlight, while animals must get a constant supply of energy through their food. They need this supply of energy to maintain their body functions: to move, to grow, to produce milk and to reproduce. Ruminants get their energy primarily from carbohydrates (sugar, starch and cellulose) and fats in the diet. The MOs in the rumen break down complex carbohydrates (e.g. cellulose – which cannot be digested by non-ruminants) into **v**olatile **f**atty **a**cids (**VFA**s), simpler molecules that can meet most of the energy needs of the animal (e.g. butyric and propionic acid). Other carbohydrates (e.g. sugars and starches) are also used for energy. Fats (found in oils) can also provide large amounts of energy when they are digested in the rumen. It might be tempting to include large amounts of fat in food rations to increase the animal's intake of energy. However, too much fat (more than about 5% of the diet) can decrease the ability of MOs to break down other parts of the diet.

If we give an animal a quantity of energy as food, we should be able to account for all of it in one form or another. What goes in must come out. Animals can lose energy in a number of ways: as excretions (e.g. feces, urine, sweat and methane), as mechanical work (e.g. pulling a cart) and as heat. Some energy can also be stored in the animal as fat. How do we ensure that an animal gets enough energy to supply its needs? We need to know how much energy the food can provide, and we need to know the energy requirements of the animal. These measurements have already been performed on a vast array of foods and animals in different stages of life. However, many of these measurements were performed on animals in temperate climates, where the cold climate can affect the energy requirements of animals. Care must be taken when using published tables of data, because the energy requirements of animals in the tropics are often lower than those of animals in temperate climates.

## Units for Energy

In books and publications on animal nutrition, different units are used around the world to define quantities of energy. The preferred unit is the **joule** (**J**), which is defined precisely with respect to certain electrical measurements. Because the joule is a very small unit, it is more common in animal nutrition publications to see the **m**egajoule (**MJ**, 1 000 000 J) or the **k**ilojoule (**kJ**, 1 000 J). Another commonly seen unit, especially in older publications, is the **calorie**, which is equal to 4.184 joules. Most publications list energy contents of foods in terms of megajoules per kilogram of the dry matter in the food (**MJ/kg dry matter**).

## Energy Definitions and Transformations

**G**ross **E**nergy (**GE**) is a very basic measurement of the energy content of food, determined by burning foods and measuring the heat produced. It is not often a very good indication of the nutritive value of a food, because foods have energy in different forms that may be more or less useful to an animal. For example, in terms of GE, wheat grain, dried grass and wheat straw have very similar amounts of energy (~18.5 MJ/kg dry matter). However, any farmer knows that an animal uses each of these three feeds very differently.

A more useful measure of energy is **D**igestible **E**nergy (**DE**). This takes into account the energy that is not digested, but rather lost in the feces (the largest single loss of energy from the diet). The DE of a food is more representative of its usefulness to an animal: less than 20% of the energy of a good quality food is lost through feces, while in a poor quality food, more than 60% can be lost this way. If we compare the DE of wheat grain, dried grass and wheat straw, we can see that the DE more accurately reflects their potential usefulness (~16 MJ/kg, ~12 MJ/kg and ~7 MJ/kg dry matter, respectively). However, supplementing feed can dramatically improve the efficiency of its use (see next article).

**M**etabolisable **E**nergy (**ME**) reflects other losses apart from feces. These include urine loss and methane produced in the rumen during carbohydrate digestion and lost through burping. These are unproductive uses of dietary energy.

There is a final energy loss to consider: **heat increment of feeding**. This is energy lost during digestion of food. If the animal eats more, it produces more heat. This is a problem in the tropics, because animals will reduce food intake (thus reducing useful production) in order to prevent overheating. The **N**et **E**nergy (NE) reflects this and is the fraction of energy input that is of direct benefit to the animal for maintenance and for actual production.

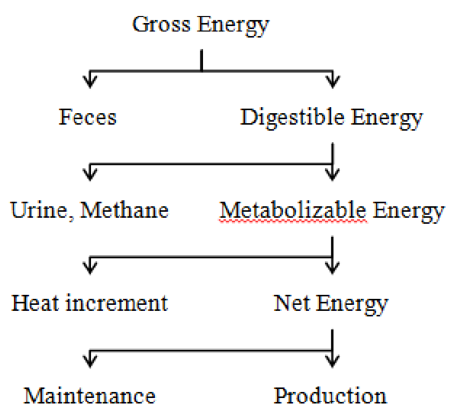


Figure 1: The overall pattern of energy use in animals.
From Ruminant Digestion by John Chesworth.

## Protein Requirements in Ruminants, Transformations, and Definitions

**Proteins** are essential in animal and plant cells. They form structural compounds, such as hair, skin and muscle, and they are regulators, or enzymes, in all internal functions. They are made up of chains of smaller compounds of **amino acids**, the building blocks of protein. About 16% of protein is **nitrogen**, and nitrogen is also important in other compounds in the body.

Non-ruminants must get almost all of their nitrogen from true protein in the diet, which tends to be the most expensive part of an animal feed. In ruminants, the MOs in the rumen need protein for their own growth and development, but they can manufacture their own amino acids and use these to manufacture protein, using simple, cheap, **n**on-**p**rotein sources of **n**itrogen (**NPN**). While the MOs are making protein for themselves, much of it passes on to the host animal, thus meeting many of the animal's protein needs. The MOs will degrade most protein in the diet to ammonia (NH3) to use as their amino acid starting point, so there is little need to use expensive, high-quality protein in the ruminant's diet – it will get broken down in the rumen before the animal can use it. This means that when feeding ruminants, you can use very cheap, simple sources of nitrogen to meet most of their protein needs (for example urea, chicken manure or ammonia). The protein that can be and is broken down by the MOs in the rumen is called **R**umen **D**egradable **P**rotein (**RDP**).

Not all the protein in the diet will be degraded by the MOs in the rumen. Some of it reaches the stomach intact, where it can be used directly by the animal. This protein is called **U**n**d**egradable **P**rotein (**UDP**) or **bypass protein**. When an animal is growing rapidly or is lactating (both of which are times of high protein needs), the protein synthesized by the MOs may not be sufficient. The animal will need a source of bypass protein.

Figure 2 details the pathways that protein in a ruminant's diet can follow. So-called **C**rude **P**rotein (**CP**) is not really a measure of protein, but rather a rough (or 'crude') estimate based upon measurements of amounts of nitrogen in the food (CP=nitrogen content x 6.25 because proteins are roughly 16% nitrogen. 16%=0.16, and 1/0.16 ~ 6.25). The CP can also include non-protein nitrogen, for example from DNA or coffee pulp.

Ruminants are able to recycle and reuse the nitrogen in urea. Instead of excreting it through the kidneys, as non-ruminants do, some urea passes through the blood stream to the salivary glands, then joins the food entering the rumen. This means that the urea can be used as a source of NPN for the MOs (though there are always some losses). Protein is also lost through the skin and hair, and it is always needed for growth and lactation.

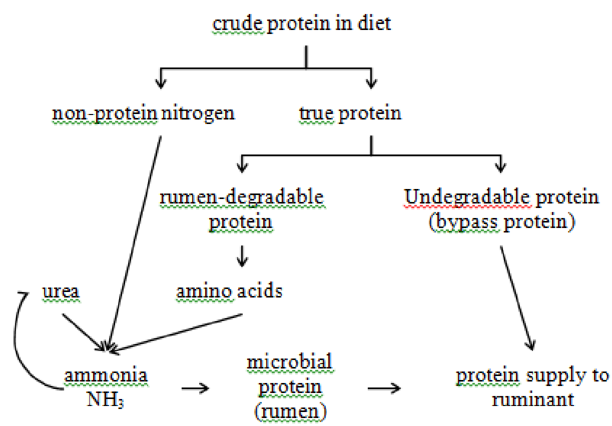


Figure 2: The paths by which crude protein in the diet arrives at the small intestine of the ruminant. From Ruminant Digestion by John Chesworth.

## Systems for Planning Animal Diets

Several systems for planning animal diets, mainly for energy needs, have been developed independently by research organizations in many different, but mainly temperate, regions of the world.

Animals in the tropics live under very different conditions than those in temperate regions. Climate can have a large effect on an animal's feed intake, digestion, water intake, and other behaviors. Climate can also affect forage quality. Animals eat less when the temperature is high. The animal's body temperature rises (due to increased heat increment of feeding) when the ruminant eats poor quality forages and this results in lowered feed intake, decreased muscle activity and slower productive functions (lower growth, milk production and reproduction rates).

Grazing time is reduced if animals are heat stressed in the middle of the day. They also require more water. As well, tropical forages mature more rapidly than temperate ones. They also have lower levels of protein, minerals and DE, and higher amounts of lignin that makes fiber less digestible.

The following article ("The Livestock Revolution") discusses some ways that forages can be supplemented to improve growth and milk production of ruminants on small tropical farms.

 