Babcock Institute for International Dairy Research and Development

University of Wisconsin-Madison

Dairy Essentials

1) DIGESTION IN THE DAIRY COW

Michel A. Wattiaux
Babcock Institute
W. Terry Howard
Department of Dairy Science

INTRODUCTION

Dairy cows and other animals such as sheep, goats, buffaloes, camels and giraffes are herbivores because their diets are composed primarily of plant material. Many herbivores also are ruminants. Ruminant animals can be recognized easily because they chew frequently even when they are not eating. This chewing activity called *rumination*, is part of the processes that allow a ruminant to obtain energy from *plant cell walls* also called *fiber*.

ADAPTATION TO UTILIZE FIBER AND NON-PROTEIN NITROGEN

Fiber is the structure than gives strength and rigidity to plants and is the main constituent of grass stems and other plant stems. Complex sugars (cellulose, hemicellulose) are locked within the plant cell wall and remain inaccessible for non ruminant animals. However, the microbial population that lives in the reticulum and the rumen (Figure 1) allows the cow to obtain energy from the fiber.

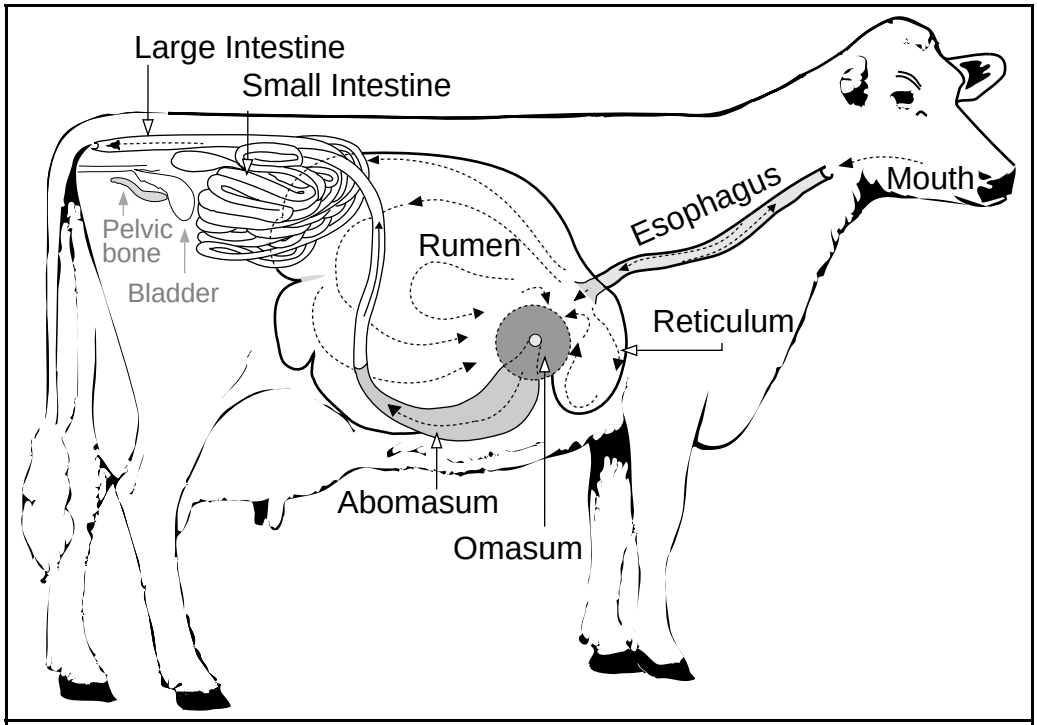


Figure 1: The digestive system of a cow includes four stomachs. The rumen is similar to a lake with a river running through one corner.

The nitrogen required in the ration of a cow comes from the amino acids found in proteins and other sources of non-protein nitrogen (NPN). Non-protein nitrogen compounds cannot be used by non-ruminants, but may be used by ruminal bacteria for the synthesis of proteins. The majority of the amino acids available to the cow comes from the bacterial protein synthesized in the rumen.

Table 1: Utilization of various energy and nitrogen sources in ruminants and non-ruminants

	Example of feed	Non-ruminant (hog, bird)	Ruminant (cow, sheep)
ENERGY			
Sugars	Molasses	+	+
Starch	Roots	+	+
Cellulose	Straws	0	±
NITROGEN			
NPN[1]	Urea	0	+
Protein	Soybean	+	+

[1] NPN = non protein nitrogen
+ completely available, ± partially available, 0 not available

THE FOUR STOMACHS

Reticulum and rumen

The *reticulum* and the *rumen* are the first two stomachs of ruminants. The contents of the reticulum is mixed with that of the rumen almost continuously (once every minute). Both stomachs, often referred to as the *reticulo-rumen*, share a dense population of micro-organisms (bacteria, protozoa, and fungi).

The rumen is a large fermentation vessel that can contain as much as 100 to 120 kg of digesting material. Fiber particles remain in the rumen from 20 to 48 hours because bacterial fermentation of fiber is a slow process. However, particles that digest faster tend to stay in the rumen for a shorter period of time.

The reticulum is the "crossroad" where particles entering or leaving the rumen are sorted. Only particles that are small is size (< 1-2 mm) and dense (> 1.2 g/ml) may move on to the third stomach.

Omasum

The third stomach or *omasum* is round (Figure 1) and has a capacity of about 10 liters. The omasum is a small organ with great absorption capacity. It allows the recycling of water and minerals such as sodium and phosphorus which return to the rumen through the saliva. Since the modes of digestion in the rumen and the abomasum differ drastically, the omasum acts as an organ of transition between these two organs. The omasum is not essential, however, as it is absent in camels, llamas and alpacas (pseudoruminants).

Abomasum

The fourth stomach is the *abomasum*. This stomach is like the stomach of non-ruminants. It secretes a strong acid and many digestive enzymes. In non-ruminants, ingested feeds are first digested in the abomasum. However, the material entering the abomasum of a ruminant is made up primarily of unfermented feed particles, some end-products of microbial fermentation and microbes which grew in the rumen.

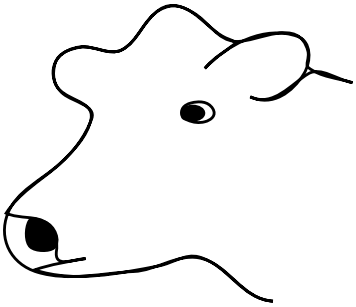
THE RUMINAL BACTERIA

The rumen provides a suitable environment with generous food supply for microbes to grow and reproduce. The absence of air (oxygen) in the rumen favors the growth of some particular species of bacteria, among them are those that can degrade plant cell walls (cellulose) into simple sugars (glucose). The microbes ferment glucose to obtain energy to grow and they produce *volatile fatty acids* (VFA) as end-products of fermentation. The VFA cross the rumen wall and become the major sources of energy to the cow.

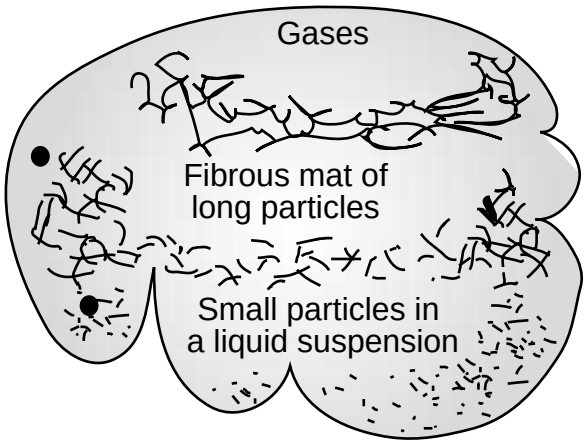
As ruminal microbes grow, they synthesize amino acids, the building blocks of proteins. Bacteria can use ammonia or urea as nitrogen sources to build amino acids. Without bacterial conversion, ammonia and urea would be useless to the cow. However, bacterial proteins synthesized in the rumen are digested in the small intestine and constitute the major source of amino acids for the cow.

THE ORGANS OF THE DIGESTIVE TRACT AND THEIR FUNCTIONS

1 - Rumination (break down of particles) and saliva (buffers) production

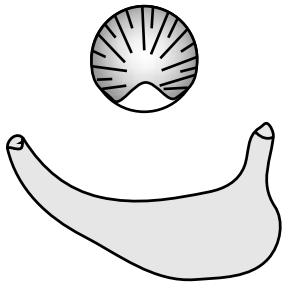


- Rumination reduces particle size of fiber and exposes sugars to microbial fermentation.
- Production of 160 to 180 liters of saliva when a cow chews 6 to 8 hours per day, but less than 30 to 50 liters if rumination is not stimulated (too much concentrate in the diet).
- *Buffers* in the saliva (bicarbonate and phosphates) neutralize the acids produced by microbial fermentation to maintain a neutral acidity which favors fiber digestion and microbial growth in the rumen.



2 - Reticulo-rumen (fermentation)

- Retention of long forage particles that stimulate rumination.
- Microbial fermentation produces: 1) volatile fatty acids (VFA) as end-products of the fermentation of cellulose and other sugars and 2) a microbial mass rich in a high quality protein.
- Absorption of VFA through the rumen wall. The VFA are used as the major energy source for the cow and also for the synthesis of milk fat (triglycerides) and milk sugar (lactose).
- Production and expulsion through belching of as many as 1000 liters of gases per day.

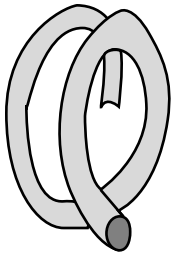


3 - Omasum (recycling of some nutrients)

- Absorption of water, sodium, phosphorus and residual VFA.

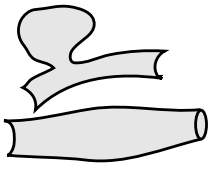
4 - Abomasum (acid digestion)

- Secretion of strong acids and digestive enzymes.
- Digestion of feed fractions not fermented in the rumen (some proteins and lipids).
- Digestion of bacterial proteins produced in the rumen (0.5 to 2.5 kg per day).



5 - Small intestine (digestion and absorption)

- Secretion of digestive enzymes by the small intestine, the liver and the pancreas.
- Enzymatic digestion of carbohydrates, proteins and lipids.
- Absorption of some water, minerals and products of digestion: glucose, amino acids and fatty acids.



6 - Cecum (fermentation) and large intestine

- A usually small microbial population ferments the unabsorbed products of digestion.
- Absorption of water and feces formation.

SOME DEFINITIONS

Absorption is the passage of the products of digestion and other simple compounds from the digestive tract into the blood.

Buffers are compounds secreted by the saliva or added to the diet that help to maintain a stable rumen, and promote feed digestion and bacterial growth.

Digestion is the first step in a series of processes that break down complex particles (feed or microbes) into simple substances that can be used by the body. A strong acid and many digestive enzymes are secreted into the digestive tract to digest food.

Metabolism refers to the changes that the absorbed products of digestion (nutrients) undergo during their utilization by the body. Nutrients may be degraded by tissues of the body to obtain energy to maintain vital functions, and to accomplish work (eating, walking, ruminating, etc.). Nutrients also may be used as precursors for the synthesis of tissues (muscle, fat) and in the case of a dairy cows the synthesis of milk.

IN PRACTICE

- Ruminant animals can use a greater variety of food sources than non-ruminant animals. The microbes living within the reticulo-rumen allow ruminants to convert fibrous feed (forages, crop residues and industrial by-products) and non-protein nitrogen (ammonia, urea) into highly nutritious and palatable food for humans (milk, meat).
- Fibrous feed is necessary for the health of the cow because it maintains rumination and saliva production which are necessary for the proper function of the rumen and to obtain the desired bacterial population within the rumen.
- A cow can eat forages (low energy feed) and concentrates (usually high energy feed). However, large additions of concentrates to a ration should be gradual (over a period of four to five days) to allow the population of bacteria in the rumen to adapt to the new diet.
- The feces of ruminants are rich in organic matter (undigested microbial debris) and inorganic matter (Nitrogen, Phosphorus and Potassium), which are excellent fertilizers.