UNIVERSITY OF SALAHADDIN-ERBIL

COLLAGE OF AGRICULTURAL ENGINEERING SCIENCES

ANIMAL RESOURCES DEPARTMENT

ANIMAL NUTRITION & METABOLISM

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Animal nutrition

Nutrition / is the process of obtaining food and then using it for obtaining energy, maintenance, growth, production and repair of the body. There are five main processes concerned with the use of food by animals. As we know that Plants produces their own food by the help of photosynthesis. But animals are heterotrophs and hence they depend on other organisms for their food. This readymade food comes either from plants or from other animals.

Animals are divided in to three groups on the basis of their food habits. These are: Herbivores, Carnivores and Omnivores.

<u>Five steps in the process of Nutrition in Animals</u>

There are five steps in the process of Nutrition in animals. These are: Ingestion, Digestion, Absorption, Assimilation and Egestion.

1. **Ingestion**: is the process of taking food in to the body or 'eating of food' by the animal.
2. **Digestion:** is the process in which the food containing large, insoluble molecules is broken down in to small, water soluble molecules which can be absorbed by the body or digestion is the dissolving of the solid food. Most of the animals include both <u>physical</u> and <u>chemical</u> methods for digesting the food. Physical method includes chewing and grinding the food in mouth (milling, pelleting) and chemical method include the addition of digestive juices (enzymes) to food by the body itself.
3. **Absorption**: is the process in which the digested food passes through the intestinal wall in to blood stream. As, after the digestion, food molecules become small and soluble. This food passes through the walls of intestine and goes in to the blood.

4. **Assimilation (utilization):** is the process in which the absorbed food is taken in by the body cells and used for energy, growth and repair. Blood carries the absorbed food to all the parts of the body.
5. **Egestion:** is the process in which the undigested food is removed from the body. The whole food which eaten is not digested by the body, a part of the food remains undigested which cannot be used by the body and so it is removed from the body in the form of faeces.

Parts of the Ruminant Digestive System

Some of the parts of the ruminant digestive system are the same as those of the monogastric digestive system, but other parts are very different. As in the monogastric digestive system, food enters into the system through the mouth and then passes through the esophagus to the stomach. In the ruminant, the stomach is divided into four compartments, called the rumen, reticulum, omasum, and abomasum. Depending on the type of feed, it may pass through all or some of these compartments as it move through the stomach. When the stomach completes its functions, the feed moves to the small intestine and proceeds through the cecum, colon, and rectum of the large intestine to the anus.

Functions of the Parts

Each of the parts of the ruminant digestive system aids in the process of extracting the nutrients needed by the animal from feed. Although the parts of the system have some similarities in function to those of the monogastric digestive system, the process of digestion is much more complex due to structure of the stomach in ruminants:

Mouth – The mouth carries feed into the digestive system.

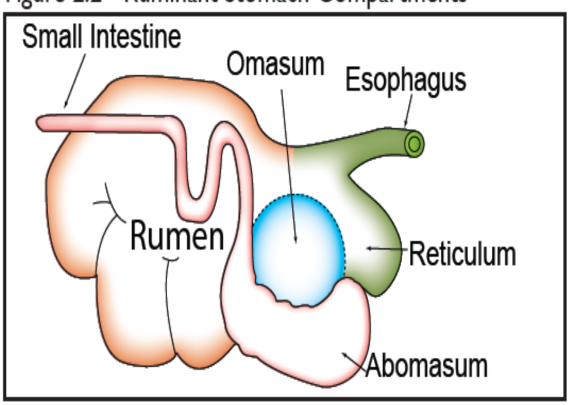
In cattle, the tongue grabs the grass or other feed and brings it into the mouth. The tongue also moves feed to the throat. The cow has front teeth only in the lower jaw, with a dental pad in the upper jaw; when grass is pulled into the mouth, the teeth cut the grass against the dental pad. The mouth also has upper and lower back teeth for chewing cud and other types of feed. Sheep use their lips to bring food into the mouth when grazing.

Esophagus - Feed is transported back and forth from the mouth to the stomach through the esophagus.

Stomach – Like the monogastric stomach, the main function of the stomach of the ruminant is to break down feed. Each of the four stomach compartments has its own unique function. Figure 2.2 illustrates the four compartments of the stomach.

a- Rumen - The rumen, which is also called the paunch, is the largest of the stomach compartments in adult animal. It helps to break feed down so that it may be digested and absorb water, ammonia and VFAs.

Figure 2.2 - Ruminant Stomach Compartments



b- Reticulum – The reticulum is also called the honeycomb because of the texture of the inner wall of the compartment.

It pumps roughage back to the mouth through the esophagus for rumination, which is the racing of feed in the form of the cud. The reticulum also works with the rumen in the breakdown of feed by microbial enzymes.

3- Omasum – The function of the omasum, or many plies, it not fully understood. However, scientists have found that the omasum absorbs some water and is involved in the absorption of nutrients.

4- Abomasum – The abomasum is referred to as the true stomach. Its functions are very similar to those of the monogastric stomach. In the abomasum, digestive juices containing acids and enzymes are added to aid in digestion.

Small intestine – In the first portion of the small intestine, called the duodenum, the digestive process started in the stomach continues. Nutrients are absorbed into the bloodstream through the walls of the remainder of the small intestine. Once the nutrients enter the bloodstream, they travel throughout the body to fuel life processes.

Large intestine – The large intestine consists of three parts the cecum, colon, and rectum. Within the large intestine of the ruminant, the cecum plays a minor role in the further breakdown of roughage. The colon absorbs water and forms undigested wastes into feces, some absorption of nutrients also takes place. The faeces are stored in the rectum before being passed out of the body.

Anus – The anus is the opening through which undigestibl solid wastes exit from the body. Any portion of the feed not absorbed into the bloodstream is excreted through the anus.

Rumination and Eructation

Ruminants are well known for "cud chewing". Rumination is: regurgitation of ingesta from the reticulum, followed by remastication and reswallowing. It provides for effective mechanical breakdown of roughage and thereby increases substrate surface area to fermentative microbes.

Regurgitation is initiated with a reticular contraction distinct from the primary contraction. This contraction, in conjunction with relaxation of the distal esophageal sphincter, allows a bolus of ingesta to enter the esophagus. The bolus is carried into the mouth by reverse peristalsis. The fluid in the bolus is squeezed out with the tongue and reswallowed, and the bolus itself is remasticated, then reswallowed.

Rumination occurs predominantly when the animal is resting and not eating, but that is a considerable fraction of the animal's lifespan.

Fermentation in the rumen generates enormous, even frightening, quantities of gas. We're talking about 30-50 liters per hour in adult cattle and about 5 liters per hour in a sheep or goat. Eructation (or belching) is how ruminants continually get rid of fermentation gases. As mentioned above, an eructation is associated with almost every secondary ruminal contraction. Eructated gas travels up the esophagus at 160 to 225 cm per second and, interestingly, a majority is actually first inspired into the lungs, then expired.

Anything that interferes with eructation is life threatening to the ruminant because the expanding rumen rapidly interferes with breathing. Animals suffering ruminal tympany (bloat) die from asphyxiation.

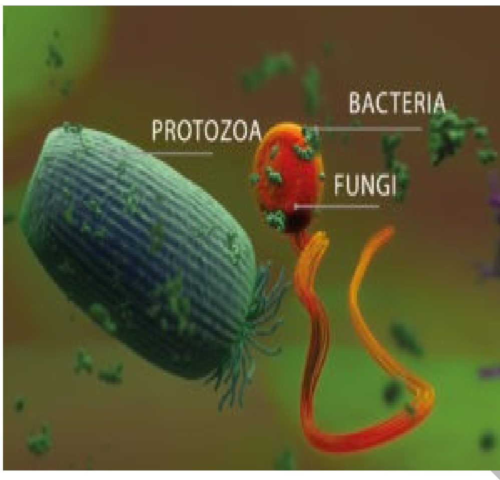
Rumen gases, particularly methane, are increasingly in the news because of their contribution to greenhouse gas and climate change. It is difficult to estimate of the contribution of ruminant digestive processes to global greenhouse gas. However, data from the Food and Agriculture Organization of the United Nations indicates that ruminants are responsible for roughly 20% of global methane emissions, which equates to approximately 3-5% of total greenhouse gas production.

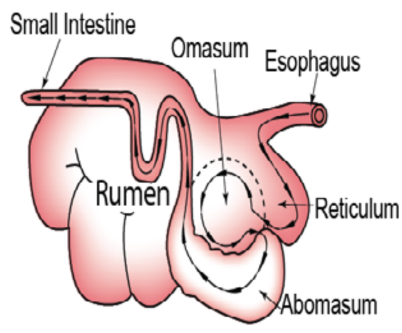
The Digestive Process

In ruminants, the breakdown of the nutrients in feed into a usable form is very complex. It involves not only the digestive juices and enzymes found in the monogastric system, but the activity of microorganisms found in the stomach. In addition, feed may take one of several paths as it passes through the stomach, depending on the nature of the feed. In contrast to the monogastric digestive system, the process of digestion does not begin in the mouth in the ruminant, since enzymes are not present in the saliva of ruminants. Instead, digestion begins in the stomach. Before feeds pass into the omasum and abomasum, they move through either the reticulum or the rumen and reticulum.

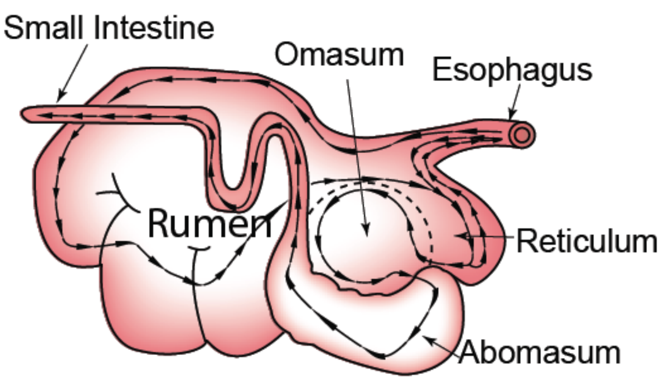
Three types of microorganisms are present in the rumen and reticulum bacteria, protozoa, and fungi.

The action of all the microorganism converts sugars, starches and fiber into fatty acids in the stomach, feed may follow one of three routes depending on the type of feed.

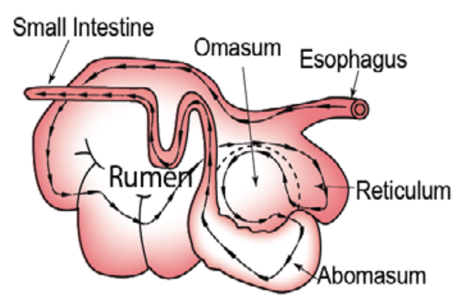




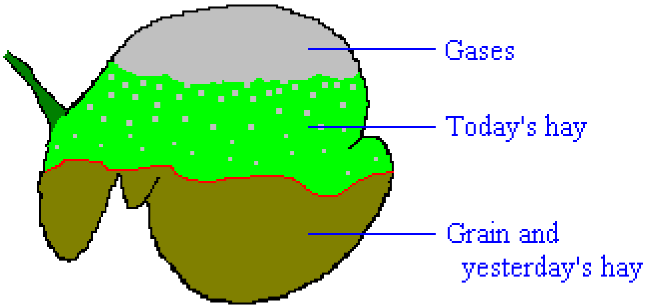
Ground Concentrates or Cud



Forages



Light Grain



In the case of a **ground concentrate or cud**, the feed passes through the reticulum where the microorganisms act on it. It then passes through the omasum, where volatile fatty acids (VFAs) are absorbed, to the abomasum. In the abomasum, gastric juices containing hydrochloric acid and the enzymes pepsin, rennin, and lipase are added to digest proteins and fats. Light grains, such as oats and barley, require a slightly more complicated path to be utilized most efficiently. They first pass into the rumen, in which muscular action breaks the feed into smaller pieces. The microorganisms then assist in digestion, and the volatile fatty acids that are produced are absorbed by the rumen. When the grain is sufficiently broken down, it passes through the reticulum and omasum into the abomasum. The third route is that taken by forages. The combination of the action of the microorganisms and the path through the rumen and reticulum are what allows ruminants to better utilize forages, which have high fiber content. As the forage passes into the rumen and reticulum, muscular action helps to break it down. The microorganisms then act on the pieces. After the microorganisms operate on the forage for a period of time, it moves to the reticulum. If the forage then needs to be broken down some more، the reticulum pumps it up through the esophagus into the mouth as cud to be chewed to break it into smaller pieces. After the cud has been chewed, the remains are again swallowed and enter the reticulum. They then pass to the omasum and abomasum. After passing through the abomasum, the feed enters the small intestine. In the duodenum, pancreatic juices are added, which include the enzymes trypsin, chymotrypsin، lipase, and amylase (of which only a small amount is present). As in the monogastric system, trypsin and chymotrypsin act on proteins, lipase on fats, and amylase on starches. Bile from the Liveris also added in the duodenum for the digestion of fats. Intestinal juices are added in the rest of the small intestine. The enzymes peptidase، lactase, sucrase, and maltase are found in the intestinal juices; peptidase works on proteins, while maltase, sucrase، and lactase work on sugars and starches. Maltase and sucrase are present in small amounts in ruminants.

All materials within the rumen partition into three primary zones based on their specific gravity. Gas rises to fill the upper regions, grain and fluid-saturated roughage ("yesterday's hay") sink to the bottom, and newly arrived roughage floats in a middle layer.

Rumen microorganisms

The rumen contains an extremely dense and diverse population of microbes that includes the 3 domains of life (bacteria, archaea and eukaryotes) as well as viruses (mainly phages). Bacteria are predominant (10^{10}–10^{11} cells per g of ruminal content) and encompass most of the metabolic functions in the rumen. Eukaryotes include protozoa (10^6 cells per g of ruminal content), which account for 30–50% of rumen microbial biomass, and fungi (10^4 zoospores per g of ruminal content). Bacteria, protozoa and fungi degrade and ferment ingested feed and convert it into short-chain fatty acids (SCFAs) and CO_2. Archaea (10^6–10^9 cells per g of ruminal content) are essentially methanogenic and mainly use CO_2 and H_2 produced by other microbes to synthesize methane. Rumen microorganisms have developed various interactions between them to ensure the efficient functioning of the trophic chain and allow microbial transformation of plant components into useful products for the host animal (mainly SCFAs and microbial proteins, also vitamins).

More than 5,000 bacterial species are estimated to be in the rumen , and the majority have no cultivated representatives. Most of these bacterial species (around 80% of sequences) belong to the phyla *Firmicutes* and *Bacteroidetes*. By comparing the bacterial phylogeny in more than 700 samples from 32 ruminant species from 35 countries, identified ubiquitous bacterial groups that represented 67% of all detected sequences: *Prevotella, Butyrivibrio, Ruminococcus* and the non-classified *Lachnospiraceae, Ruminococcaceae, Bacteroidales* and *Clostridiales*. Their proportions also vary according to the fraction: free in the liquid phase, attached to food particles or attached to the ruminal epithelium. Using classical morphological criteria, more than 25 genera of protozoa have been identified in the rumen .18 genera of anaerobic fungi have been described, but this number could be further extended because metataxonomic analyses have identified additional clades. The total number of rumen protozoa genera and species is probably still underestimated. The diversity of rumen methanogenic fungi is limited to 4 orders; the viruses (estimates of up to 10^9–10^{10} per ml of ruminal content) have different morph types and belong mostly to the families *Siphoviridae*, *Myoviridae* and *Podoviridae* (*Caudoviridae* order). They probably play a role in the dynamics of bacterial populations through their lysis activity, thus participating in the recycling of nutrients (proteins and DNA) and enabling the transfer of genetic material.

When diets are rich in fiber (i.e. not cereal diets or young pasture herbage). The rumen microorganisms can be envisaged as operating together, as so-called consortia, to attack and break down foods. Some, like the fungi, are capable of in vading and colonising plant tissues; others follow up to ferment the spoils of the invasion.

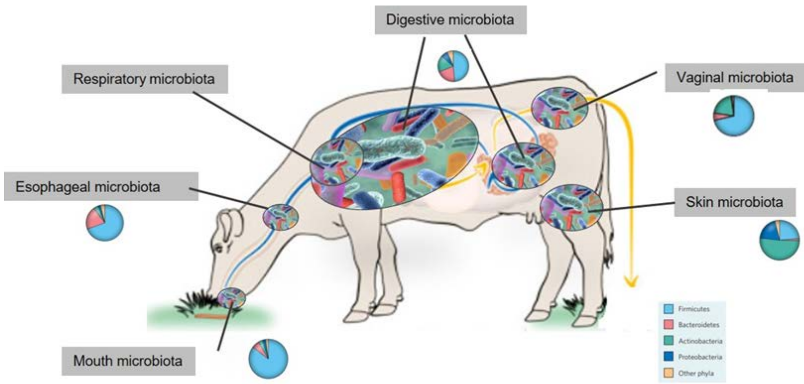
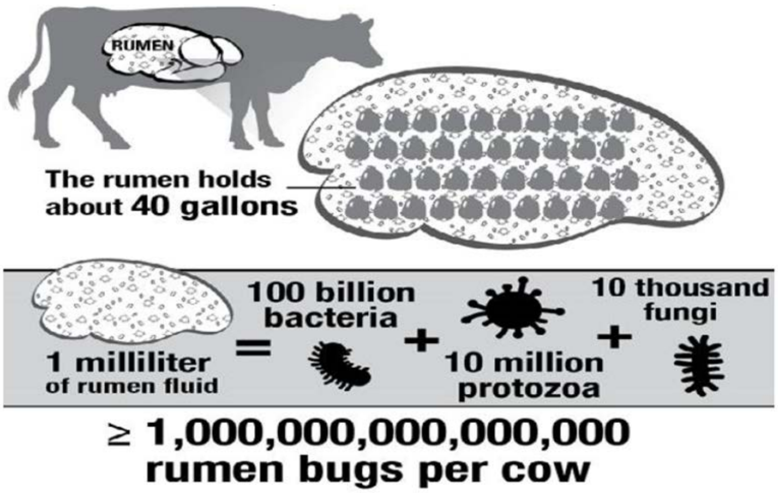


Table ( ) typical rumen bacteria, their energy sources and fermentation products in vitro

Species	Typical energy sources	Alternative energy sources
Fibrobacter Succinogenes	Cellulose	Glucose (starch)
Ruminococcus flavefaciens	Cellulose	Xylan
Ruminococcus albus	Cellobiose	Xylan
Streptococcus bovis	Starch	Glucose
Prevotella ruminicola	Glucose	Xylan, starch
Megasphaera elsdenii	Lactate	Glucose, glycerol
Lachnospira multipara	Pectins	Glucose, fructose

As the microbial mass synthesised in the rumen provides about 20 % of the nutrients absorbed by the host animal, the composition of microorganisms is important. The bacterial dry matter contains about 100 g nitrogen/kg, but only 80 % of this is in the form of amino acids, the remaining 20 % being present as nucleic acid nitrogen.

Moreover, some of the amino acids are contained in the peptidoglycan of the cell wall membrane and are not digested by the host animal.



Factors affecting microbial protein synthesis

1-The level and source of energy in the diet

2- The level and source of protein in the diet

3-Intake level and feeding frequency

4-Synchronization between degradation of protein sources and energy sources

5-Effect of anti-nutrients on microbial protein synthesis

6-The ratio of concentrated feed to roughage fodder

7-Effect of rumen pH and rumen environment

8-Minerals and vitamins

The importance of microbial protein in ruminant feed

Amino acids produced by rumen microbes are available to ruminants in the small intestine. When the microbial protein flows with the digested material towards the lower parts of the digestive system, microbial protein is a stable source of high quality containing balanced amino acids it is also relatively less expensive compared to other crude protein sources. The composition of amino acids in the microbial protein synthesis in the rumen is stable and independent of the diets. that the composition of amino acids in the microbial protein of organisms was not modified by changing the type and level of the crude protein source or by including volatile branched-chain fatty acids in the diets, as the microbial protein contains the following amino acids (Isoleucine 5,8 ± 0,7, Leucine 8,0 ± 0,8, Lysine 9,2 ± 1,8, Methionine2,5 ± 0,6, Cysteine 1,4 ± 0,9, Phenylalanine 5,3 ± 0,7, Tyrosine 4,9 ± 0,6, Threonine 5,7 ± 0 , 8, Tryptophan 1,5 ± 0,8, Valine 5,8 ± 0,9, Arginine 5,3± 1,0, Histidine 2,1 ± 0,5, Alanine 6,8 ± 1,6, Aspartic acid 11,9 ± 1,6, Glutamic acid 12,4 ± 2,3, Glycine 5,4 ± 0,5, Proline 3,6 ± 1,1 , Serine 4,7 ± 0,6, Diaminopimelic acid 0,8 ± 0,3) g amino acids / 100 g microbial protein , the digestibility of amino acids in the small intestine is about 85%, except for Diaminopimelic acid, Which has low digestibility as the microbial amino acids absorbed by the animal are used in about 80%. The ruminant animals jointly derive the amino acids from the dietary protein escaping from degradation in the rumen and the microbial protein synthesis in the rumen, the microbial protein is a major source of the amino acids for ruminants, while asserted that microbial protein contributes the largest amount up to duodenum for ruminants, and although the microbial protein is characterized by a high proportion of NPN (25%), it has a major role in feeding ruminants , since rumen microbes provide protein for maintenance purposes, slow growth and early pregnancy, but not for rapid growth and the onset of milk production, however, emphasized the importance of efficient microbial protein synthesis to support high levels of production, in projects productivity in tropical regions, where roughage feed is the basis of the diet, microbial protein may provide

100% of the protein available to ruminants in these areas. Microbial protein is a final product of carbohydrate fermentation in the rumen, so growth yield is often expressed; the microbial denotes it as nitrogen or microbial protein per kilogram or 100 gram of digestible organic matter.

Table 8.3 Typical rumen bacteria, their energy sources and fermentation products in vitro

Species	Description	Typical energy sources	Typical fermentation products (excluding gases)						Alternative energy sources
			Acetic	Propionic	Butyric	Lactic	Succinic	Formic	
Fibrobacter succinogenes	Gram-negative rods	Cellulose	+				+	+	Glucose (starch)
Ruminococcus flavefaciens	Catalase-negative streptococci with yellow colonies	Cellulose	+			+	+	+	Xylan
Ruminococcus albus	Single or paired cocci	Cellobiose	+					+	Xylan
Streptococcus bovis	Gram-positive, short chains of cocci, capsulated	Starch				+			Glucose
Prevotella ruminicola	Gram-negative, oval or rod	Glucose	+				+	+	Xylan, starch
Megasphaera elsdenii	Large cocci, paired or in chains	Lactate	+	+	+				Glucose, glycerol
Lachnospira multipara	Gram-positive curved rods	Pectins	+				+		Glucose, fructose