CHAPTER 8 Rumen metabolism

Ruminants fulfill a key role in converting plant resources other animals cannot consume in to desirable high quality human foods. The reason ruminants occupy such an important role in the production of human food is due to their enlarged forestomach or rumen.

The rumen serves as an ideal habitat for a large and diverse population of anaerobic microbes living in symbiosis with the ruminant animals. It provides its microbe inhabitants protection, a supply of nutrients and consistent temperature and pH required for their optimal growth and reproduction, the ruminant animal as a result of the metabolic activities of these microorganisms derives the so called *volatile fatty acids*, which are formed as end products during the fermentation of different classes of compounds carried out by the rumen microbes.

The symbiotic relationship also provides the ruminant animal with relatively high amounts of some vitamins particularly vitamin K and the B-vitamins. Furthermore, some of the microbes that continually enter the intestinal tract of the host animal are digested by enzymes secreted by the stomach lining to yield amino acids, sugars and other hydrolysis products that are absorbed and thus become available for the nutrition of the ruminant animal.

Each rumen microbial species has a specific fermentation pattern so that the proportion of the volatile fatty acids formed varies as do relative members of the several microbial species.The volatile fatty acids primarily; *acetate, butyrate,* and *propionate* become absorbed in to the blood stream of the ruminant animal, taken up by the tissues and are used as fuel. Some of these fatty acids are also used for other purposes such as fat synthesis e.g. acetate and butyrate or glucose synthesis e.g. propionate.

**8.1. Products of rumen metabolism**

*Carbohydrates* are the predominant food components of ruminant animals. Thecarbohydrates degraded in the rumen include pentoses, hexoses, starch, cellulose, hemicellulose and pectins. The largest portion of each carbohydrate degraded is fermented to form the volatile fatty acids; variable proportions of the carbohydrates are also used as carbon sources by the microorganisms.

Cellulose, a major plant polysaccharide cannot be digested by vertebrates for lack of the enzyme, ***cellulase*** that hydrolyzes the β-1,4 linkage between successive glucose units of cellulose. For most vertebrate animals hence, cellulose has no food value, but provides bulk/fiber in the diet and is responsible for the proper motility of the intestine.

Cellulose containing feed materials; grass, hay and silage can however be indirectly digested and used as food by ruminant animals. Cellulase producing bacteria and protozoa occurring in the rumen of ruminant animals (as well as in the cecum of other animals like rabbits, horses etc.) secrete cellulase that hydrolyzes cellulose to cellobiose (a disaccharide form of cellulose), which becomes degraded by another enzyme (β-glucosidase) to form glucose. The so formed glucose undergoes fermentation processes to yield the volatile fatty acids which are then absorbed by the blood and used by the ruminant animal.

*Lipids*; dietary triacylglycerols and phospholipids are largely hydrolyzed in the rumen yielding glycerol and fatty acids. Glycerol is fermented by the microbes in much the same way as is carbohydrate. Unsaturated fatty acids released become extensively hydrogenated by the microbes forming saturated fatty acids, which accounts for the reason why fats in animal products are highly saturated.

Fat that escapes hydrolysis in the rumen is digested in the lower gut by the same mechanisms as in simple-stomached animals. Fat escaping rumen digestion and lipids in microbial membranes satisfy the essential fatty acid requirement of ruminants.

*Proteins;* are rapidly hydrolyzed to amino acids by the rumen microbes. A portion of these are used for microbial growth, and the remainder is degraded to form volatile fatty acids and ammonia. Ammonia formed from the amino acids and dietary non protein nitrogen sources, such as plant nucleic acids serve as nitrogen sources for microbial growth.

Urea formed as an end product of amino acid catabolism by the ruminants becomes secreted in to the rumen, where it becomes a substrate for a microbial enzyme called ***Urease***. This enzyme catalyzes the degradation of urea in to carbon dioxide and ammonia, according to the reaction;

H2N – CO – NH2 + H2O → CO2 + 2NH3

The ammonia so formed is used by the microorganisms to produce amino acids, which are then absorbed and used by the ruminant animal. The camel by secreting urea in to its GI tract and recycling it in the same way avoids water loss connected with the urinary excretion of urea, enabling it to get along with a very small water intake.

**8.2. Metabolism of absorbed nutrients**

The volatile fatty acids are produced in large amounts through ruminal fermentation and are of greatest importance in that they provide a substantial amount of the ruminant's energy supply. Virtually all of the major volatile fatty acids formed in the rumen are absorbed across the ruminal epithelium, from which they are carried by ruminal veins to the portal vein and to the liver.

All the volatile fatty acids appear to be absorbed by the same mechanism, which is diffusion through the epithelium and as they pass through the epithelium, they undergo different degrees of metabolism; acetate and propionate pass through the epithelium largely unchanged, but almost all of the butyrate becomes metabolized in the epithelium to β-hydroxybutyrate.

The three major volatile fatty acids have somewhat distinctive metabolic fates:

* *Acetate* is utilized minimally in the liver, but it is oxidized throughout most of the body to generate ATP. A major use of acetate is to provide energy for maintenance functions, growth and lactation. Its oxidation can also provide NADPH2 required for fatty acid synthesis. Adipose- tissue is the primary site of synthesis of fatty acids from acetate for incorporation in to storage triacylglycerols.
* *Butyrate*, most of which comes out of the rumen as β-hydroxybutyrate, is oxidized in many tissues for energy production. β-Hydroxybutyrate also serves as a carbon source for synthesis of fatty acids in milk fat.
* *Propionate*,among the volatile fatty acids, only propionate can serve as a precursor for gluconeogenesis and be used for glucose synthesis by the ruminant animal. The role of propionate is critical to the ruminant animal, because ruminants absorb inadequate amounts of hexoses due to the rapid fermentation of sugars and starch in the rumen (in the cow, for example only a few grams of unfermented glucose pass from the intestinal tract in to the blood stream in a 24 hour period).

Ruminants like non ruminants need blood glucose not only to supply the brain and other glucose-dependent tissues with fuel but also as a precursor of glycolipids and lactose if they are lactating. The significant quantities of glucose required by the ruminant animal are synthesized from propionate and amino acids via gluconeogenesis; a small amount of lactate formed in the rumen by bacterial fermentation is also converted in to glucose by the liver.

**Ketosis**

Ketosis; an increase in the level of ketone bodies in blood, is a metabolic problem encountered in producing ruminants; in *preparturient ewes* and *postpartum dairy cows* that leads to reduced feed intake and acidosis.

It is thought to be associated with extensive removal of glucose from circulation to provide glucose required by, usually, twin lambs during late pregnancy in the ewe and for lactose synthesis in the high producing dairy cow. The hypothesis, that ketosis results from a shortage of glucose is supported by the fact that successful therapy for ketosis includes intravenous administration of glucose and administration of glucocorticoids, which increase blood glucose.