The Biochemistry of Ruminant Nutrition

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Introduction

The ruminant animal has two special adaptations for which it is characteristically noted. The first of these is the adaptation of the digestive tract to the ingested nutrients. One part of this is anatomical in the form of the four-compartment stomach and one part is biochemical in the form of rumen fermentation.

The second is the adaptation of the tissues to the end products of digestion, notably the short chain, volatile fatty acids and the simultaneous production of large quantities of bacterial cell protein.

The animal thus has a capacity for utilization of feedstuffs not usable by other species. These include cellulose and inorganic nitrogen.

The large storage compartment made up mostly by the rumen also gives the animal a capacity for surviving comparatively long periods without feed or water.

As would be expected, the distinctive features of the ruminant digestive tract and its accompanying processes result in a wide range of nutritional, metabolic and other disorders that are quite different from those observed in other species. These include ruminant ketosis, bloat, traumatic reticulitis, feed engorgment, rumenitis and the various impactions and displacements of the gastric compartments. Toxicities associated with the over ingestion of urea, nitrates and cyanogenic glucosides are also characteristically different in ruminants.

Much knowledge of rumen function has come from studies that have been stimulated by interest in one or more of these disease processes.

It should be recognized that the newborn calf has a digestive system that is not markedly different from that of simple stomached animals. The calf therefore requires a highly digestible ration, and attempts to supplement the diet with coarse roughages may lead to digestive problems. If the calf is allowed to develop normally the stomach soon becomes "compartmentalized" and at the age of two to four months development has proceeded so that the rumen, reticulum and omasum begin to carry out a larger share of the digestion.

Rumen Fermentation

The microflora of the rumen provide a capacity for utilizing crude fiber and inorganic nitrogen that is not possessed by simple stomached animals. The microorganisms also provide the ruminant a supply of water soluble vitamins, including B_{12} if traces of cobalt are available in the ration.

The overall process is appropriately termed fermentation. Fermentation in the classical sense refers to the dissimilatory processes of metabolism in which molecular oxygen plays no role. It is characterized by the production of little energy but a considerable amount of end product. The specific end products produced depend on the species of microorganisms present, the nature of the environment and the substrate or medium upon which the organisms grow. In the case of the ruminant, the medium is the ration feed to the animal. The usual fermentation end products are the volatile organic acids, principally acetic, butyric and propionic acids. The relative proportions vary somewhat with the ration fed but are usually approximately 65% acetic, 15% butyric and 20% propionic. These organic acids are readily absorbed and constitute the principal energy sources available to the animal from digestive action on the ingested carbohydrate.

A sudden change to a more highly fermentable ration may lead to a drastic change in the rumen microflora and the resulting end product. Usually there is a great increase in lactic acid production, a resulting decrease in rumen pH, an increase in osmolarity and the well known syndrome of engorgement toxemia results.

Lipids and proteins in the ingested ration are degraded in much the same fashion but the resulting end products are slightly different. Probably a higher percentage of propionic acid results from lipid fermentation. Much of the nitrogen of the protein molecules can be expected to become bacterial cell protein to be further digested in lower portions of the tract.

Cellular Respiration

The soluble sugars and other carbohydrates of the ingested ration reach the blood stream in the form of short chain, volatile fatty acids. The ruminant however is not completely adapted to life without glucose. It has lower levels than are usually found in other species but it must have some to maintain normal body functions.

The glucose needed must be synthesized from the fermentation end products. The liver is the usual site for this formation. As would be expected, this type of reaction is an energy requiring process. The energy is needed in the form of phosphorylated nucleotides, principally adenosine tri-phosphate or ATP. The ruminant develops this energy, again in the liver and other soft tissue organs, by further degradation of fermentation end products.

The short chain fatty acids are further degraded to the final end products of CO_2 and water. The dissimilatory pathways by which these reactions take place are called cellular respiration. Respiration, as contrasted with fermentation, results in few end products but yields considerable energy in the form of ATP. Molecular oxygen must be consumed in the process.

Gluconeogenesis

The ruminant, like other animal organisms, stores very little carbohydrate as carbohydrate. Some is stored as liver glycogen and muscle glycogen and a plasma glucose level of approximately 50 mg % is usually maintained.

Carbohydrate for the most part however is stored as body fat. In situations where the short term stores of carbohydrate become overtaxed the animal must call upon its reserves of tissue lipids and proteins as sources of glucose. This is generally an inefficient and biologically wasteful process but does suffice to meet the biological demands placed on the animal in most cases.

In some conditions, such as excessive lactation or other stress requiring both glucose and energy the system appears to break down logistically and the animal becomes clinically ill. Usually the syndrome is one of hypoglycemia and ketonemia. The ketones are produced again in the liver as end products from the incomplete oxidation of long chain fatty acids or body fats and indicate a shift to fat metabolism on the part of the body tissues.

All of these processes are of course complex and are regulated at least in part by enzymes, vitamin co-factors and hormones.

We sometimes make use of these pharmacologically. The adrenal cortical steroids for example favor amino acid mobilization and gluconeogenesis and are frequently used for this purpose.

References

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