Exploring microbial digestive dynamics of ruminants in vitro

Ruminants such as cattle possess a complex system of microorganisms in the gut which facilitate the breakdown of plant material. Pioneering studies in ruminant microbial ecology and health are being conducted by Dr Marshall D Stern and Dr Andres M Gomez from the University of Minnesota. Using a dual flow continuous culture system to mimic in vivo conditions, Dr Stern and Dr Gomez are investigating effects of various compounds on microbial fermentation and ecology using the in vitro system.

The animal has a complex biological system comprised of a variety of chemical structures and a community of microorganisms that facilitate the breakdown of plant material. Because of the complexity of this system, it is essential to understand the biology of these microorganisms, the role they play in facilitating nutrient utilisation and their sensitivities to certain compounds that may have either deleterious or beneficial effects on nutrition and health. Investigating these issues using a non-invasive method are Dr Marshall D. Stern and colleagues from the University of Minnesota.

RUMEN BIOLOGY

Herbivorous animals such as cattle are ruminants which acquire nutrients from plant-based materials through a complex system of fermentation. This fermentation process, known as pre-gastric fermentation, is facilitated by microorganisms in the gut, or rumen, and allows ruminants to obtain energy from plants. Plant material such as cellulose is digested by the enzyme cellulase secreted by these microorganisms in the gut. Without this system, cellulose would not be digested by animals.

Besides digestion of cellulose, the system also allows microbes to synthesise protein from nitrogen, denitrify plant compounds, reduce the number of required B vitamins, and subsequently increase the efficiency of absorption of end-products in the lower gut. Therefore, studying this system in greater detail allows for a better understanding of the compounds and mechanisms involved in pre-gastric fermentation and thus developing methods for optimum nutrient absorption in cattle.

NON-INVASIVE METHODS

In vitro models provide a non-invasive way of studying the “the rumen”, which is the first compartment of the stomach. Dr Stern and colleagues from the University of Minnesota utilise the continuous culture system to study various factors that affect rumen microbial fermentation and ecology. This in vitro study system is said to mimic in vivo conditions by maintaining microbes in an environment similar to that of the rumen. Conditions such as temperature, pH and digesta flow are maintained in this study system. Compared to using animal models, the continuous culture system is less harmful, less expensive, less time-consuming and more controlled.

Recently, Dr Stern and his graduate student, Isaac Sailer, and other colleagues examined similarities and differences between bacterial and archaeal communities in the rumen of dairy cattle compared to the in vitro continuous culture system. Previous research using culture systems and oligonucleotide techniques established that some microbial populations in vitro may be maintained at abundances similar to the in vivo conditions in ruminants. By sequencing ribosomal bacterial and archaeal genes, Dr Stern’s laboratory investigated whether microbial communities and their abundances differed between the in vitro and in vivo conditions. Their results showed that while communities differed, the most abundant species were maintained across both study systems. This lends weight to the efficacy of in vitro culture systems for studying rumen conditions in a non-invasive way.

IN VITRO IN ACTION

This continuous culture system enables Dr Stern’s research group to study potentially negative effects of certain compounds on microbial growth and fermentation. One such compound is patulin, a secondary metabolite of toxigenic strains of Penicillium, Aspergillus and Byssochlamys species which are common contaminants of fermented feeds. It is understood that patulin is toxic to many organisms and possesses an antimicrobial effect. In fact, Penicillium-contaminated silage has been found to be associated with hemorrhagic disorders in cattle. With this understanding, Dr Stern and colleagues evaluated the effects of varying concentrations of patulin on microorganisms in the in vitro continuous culture fermenters.

In vitro models provide a non-invasive way of studying the rumen compartment of cattle and sheep.

Results of this study confirmed that patulin can alter metabolic processes associated with nutrient absorption and disrupt the production of bacterial end-products. Dr Stern and colleagues have postulated that due to the interconnectedness of ruminal microbial populations, these changes could be have come about by direct inhibitory effects of patulin on bacterial growth or through a lack of essential nutrients from an altered food chain. Thus, these alterations may have negative consequences on the health and performance of ruminants such as cattle and sheep.

Using the same fermentor system, Dr Stern and colleagues also investigated the effects of the sulphur binder bismuth subsalicylate (BSS) on the production of hydrogen sulphide gas, H2S.
Compared to using animal models, this system is less harmful, less expensive, less time-consuming and more controlled.