Modulation of gut health in beef,

Several compounds that target gut health for beef and dairy cattle production have become available, and their effects are being explored as alternatives to antibiotics.

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THE gastrointestinal tract, or gut, was historically considered an organ equipped solely for the digestion and absorption of nutrients. However, recent data have illuminated the gut acts in concert with the brain and peripheral organs and is capable of adapting in response to substantial changes in its environment (Spor et al., 2011).

The gut harbors the largest population of immune cells in the body, as well as the commensal bacteria that outnumber the entire amount of host cells. The gut is also lined with a complex network of neurons known as the enteric nervous system, or "second brain," which controls many gut functions, such as digestion and response to infection and non-infectious stressors. There is a general consensus that a healthy gut leads to a healthy animal with optimal performance.

Understanding the interactions between these interrelated components of the gut is what cumulatively makes the gut the basis for the health and productivity of beef and dairy cattle.

Over the past 20 years, there has been a growing concern for public health related to the use of antibiotics in livestock production due to the potential for antimicrobial resistance. The use of medically important antibiotics in feed or water can no longer be claimed for growth promotion in the U.S. All medically important antibiotics were moved to the veterinary feed directive status for only disease treatment or prevention and now require veterinary oversight.

To ensure animal health and productivity, there is an urgent need to find alternatives to antibiotics, and new strategies must be developed. As animal health and performance are directly linked to the gut, nutrients and compounds that promote gut health have the potential to replace in-feed antibiotics and should be explored intensively.

Critical functions

The large number of epithelial, immune, neural and commensal bacterial cells lining the gut and their complex interplays make the gut the most important organ for animal health and performance. The ability of the gut to perform normal physiological functions and help the animal maintain homeostasis requires the ability to withstand environmental and infectious stressors that occur in commercial beef and dairy operations.

Gut health is manifested by effective digestion/absorption of nutrients, a balanced microflora, a functional gut barrier and an effective immune system, all of which play a critical role in maintaining gut homeostasis and the productivity and well-being of the ruminal animal.

- **Effective nutrient digestion and absorption.** Proper gut development and function are essential for efficient digestion and absorption of nutrients. Impaired gut function can have long-lasting negative effects on overall animal health, production and end-product quality. For example, diarrhea in early life has been shown to have a negative impact on milk production and components of dairy heifers (Heinrichs and Heinrichs, 2011).

To maximize the absorption of nutrients from feed, the mucosa must maintain a large surface area. This is achieved through the lining of the gut being arranged into folds of finger-like projections called villi. Damage to or alterations in this structure can lead to a decrease in the area of the gut available to absorb nutrients while increasing the chance of inflammation and bacterial translocation.

Factors such as diet and disease play an important role in the development and maintenance of the villus structure. Compounds or nutrients that promote mucosal health have the potential to improve nutrient digestion and absorption.

- **Maintenance of a stable and favorable microflora.** Another key factor in the development and preservation of gut health is its natural microbial composition. Trillions of microorganisms are present in the gut, including bacteria, protozoa, fungi, archaea and viruses, although bacteria and protozoa predominate in the rumen.

Establishment of host-specific gut microorganisms plays a crucial role in development of the mucosal immune system and influences their susceptibility to enteric infections. The development of this community of microorganisms begins at birth and is influenced by bacteria picked up from the dam and the environment (Fouhy et al., 2012; Rodriguez et al., 2015). The presence and maintenance of beneficial bacteria is essential for maintaining gut function. It is known that the commensal microbiota contributes to gut health mainly by preventing colonization of enteric pathogens, increasing digestive capacity, lowering pH, producing beneficial metabolites such as short-chain fatty acids (SCFA) and improving mucosal immunity and barrier function (Uyeno et al., 2015). All of these mechanisms are not mutually exclusive and are likely to occur in combination to help maintain a healthy gut.

- **Maintenance of a healthy and functional mucosae.** A single layer of epithelial cells that serve to facilitate the digestion and absorption of nutrients and also act as a barrier to invading microorganisms, toxins and dietary antigens. Intestinal barrier function is achieved through coating the epithelial cells with a mucus layer and the formation of a selectively permeable barrier across and between epithelial cells (Turner, 2009).

The mucus layer consists primarily of mucin glycoproteins that are secreted by goblet cells, functioning as a physical barrier between the luminal contents and the host and also facilitating nutrient digestion and absorption (Johansson et al., 2013).

However, the primary barrier function of the gut resides with epithelial cells, which transport water, ions and macromolecules through either transcellular or paracellular pathways (Groschwitz and Hogan, 2009; Turner, 2009; Resgna, 2011). The transcellular pathway refers to the movement of small molecules through epithelial cells either by active or passive transport, whereas the paracellular pathway refers to the diffusion of water, macromolecules and immune cells between epithelial cells.

In the presence of intact epithelial cells, the paracellular pathway dictates the intestinal permeability through formation of both tight junctions and adherens junctions, each of which is assembled by a myriad of proteins that are regulated by infection and non-infectious stressors.

- **Maintenance of effective immunity.** The gut is not only an organ used for nutrient digestion and absorption, but it’s also an important immune organ, possessing the largest mass of the lymphoid tissue in the body that is collectively referred to as gut-associated lymphoid tissue (GALT). Various types of immune cells such as T and B lymphocytes, macrophages and/or dendritic cells are scattered within the gut epithelium and, more frequently, aggregated discretely in the lamina propria beneath the epithelial layer throughout the digestive tract.

Along with intestinal development, the GALT develops during the fetal stage and matures following exposure to microorganisms after birth. In addition, intestinal epithelial cells increase the absorptive surface area and development of a selective gut barrier. FGFs are critical with mucosal defense and homeostasis, which is achieved through secretion of an array of mucus, cytokines, antimicrobial peptides and gut hormones (Hooper, 2015). These mediators are synthesized either constitutively or inducibly in response to stress, infection, dietary or environmental changes.

What compromises gut health?

Besides infection, many management and environmental factors can compromise gut health in beef and dairy cattle. These include weaning, molds and mycotoxins in feed, heat stress, transportation, transition to rapidly fermentable feeds, etc. Weaning under modern-day commercial conditions inflicts stress (environmental, nutritional, psychological and social) and is associated with marked changes in gut physiology, microbiota and immunity (Wood et al., 2015).

Consequently, postweaning animals often suffer from suboptimal growth and feed efficiency, with a high incidence of diarrhea that can increase morbidity and/or mortality. Moldy feed reduces the palatability, digestibility and energy content of the feed that, in turn, causes reduced animal health and performance.

Gut barrier function, immunity and performance will be further compromised if an animal consumes feed that contains molds producing harmful levels of mycotoxins. Diarrhea, intestinal hemorrhaging, reduced fertility/conception and/ or abortions are often the gross evidence of mycotoxin consumption.

Heat and transportation can also cause stress-induced immune suppressions and deterioration of gut integrity, among other effects. Dietary interventions are often needed to mitigate the many management and environmental stressors that can potentially compromise gut health, productivity and the...