Modulation of gut health in beef, dairy cattle vital to productivity

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 shown that 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 noninfectious 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 antimicrobial resistance. The use of medically important antibiotics was moved to 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.

A healthy gut 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 ruminant 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 component yields of dairy heifers (Heinrichs and Heinrichs, 2011).

To maximize the absorption of nutrients from feed, the mucosa has to 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 in newborn ruminants 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 gut barrier.** The gut is lined by 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 Turner, 2009; Rescigno, 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 cell migration through intercellular spaces.

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 stresses.

• **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 the 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, aggregate discretely in the lamina propria beneath the epithelial cells.

In gut physiology, microbiota and immunity 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 hemorrhage, reduced fertility/conception and/or abortions are often evidence of mycotoxin consumption.

Heat and transportation can also cause stress-induced immune suppression and deterioration of gut barrier 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 well-being of beef and dairy cattle.

A variety of dietary compounds have been shown to exert beneficial effects on gut health. A better understanding of the mechanisms whereby these compounds influence gut physiology and further explorations of possible synergistic actions among different compounds may lead to the development of more effective alternatives to antibiotics for growth promotion, disease control and prevention.

**Present work, implications**

Within the livestock industry, the number of dietary compounds commonly used for improving gut health is far greater for monogastrics than ruminants. Several classes of bioactive compounds exist with gut health applications, such as probiotics, prebiotics, essential oils, organic acids, minerals and AMP.

Probiotics, also known as direct-fed microbials (DFMs), are defined as live microorganisms that confer a health benefit for the host when administered in adequate amounts. Following ingestion, DFMs can modulate the balance and activities of the gut microbiota by limiting the nutrient availability to pathogens and/or producing organic acids and bacteriocins (Krehbiel et al., 2003). Single or mixed strains of probiotic bacteria have been used in beef and dairy production with a generally beneficial effect.

Prebiotics are non-digestible feed ingredients that can be fed to alter the composition or metabolism of the gut microbiota in a beneficial manner. Prebiotics, such as galacto-oligosaccharides, fructo-oligosaccharides, inulin and mannan oligosaccharides have been used to increase the proportion of beneficial bacteria in the gut (Uyeno et al., 2015). To explore the synergistic beneficial effect on the host, commercial products containing both probiotics and prebiotics, known as symbiotics, are also being used.

Phytochemical feed additives such as essential oils achieve beneficial effects through the amelioration of feed properties, selective inhibition of bacterial growth and improvement of the quality of animal food products. Organic acids are organic compounds with generally weak acidic properties. The most-studied organic acids with respect to ruminants are SCFA, which are the end products of microbial fermentation in the rumen and hind gut. SCFA butyrate in particular has beneficial effects on the host by serving as the primary energy source of the hind gut, stimulating epithelial cell differentiation and promoting gut barrier function and AMP synthesis while suppressing gut inflammation and oxidative stress.

Minerals such as zeolites can prevent diarrhea by increasing the absorption of intestinal immunoglobulin, bile acids (endogenic cause of diarrhea) and glucose (a high content of which in intestinal fluid acts as an irritant factor).

AMP, also known as host defense peptides, is a critical component of an animal’s innate immunity with direct antimicrobial, immunomodulatory and barrier protective properties (Robinson et al., 2015). Administration of AMP enhances performance and intestinal barrier integrity while reducing the incidence of diarrhea in mice and postweaning pigs (Yan et al., 2015). Diet also plays a determinant role in the ability of the compounds with the ability to induce endogenous AMP synthesis also improves disease resistance in humans and monogastric animals (Lyu et al., 2015). It will be interesting to evaluate the efficacy of supplementing AMP or AMP-inducing compounds in disease control and prevention in ruminants.

**Conclusions**

Maintaining gut health is essential for beef and dairy cattle production. Several different classes of compounds that target gut health have become available. However, their overall beneficial effect is rather marginal compared with in-feed antibiotics. There is an emerging trend to explore the synergistic or additive effect of some of the compounds. The recent influx of research investigating how different compounds influence gut health will benefit the ruminant animal.

The breadth of nutritional technologies now common in monogastric animals, but untested in ruminants, also offers valuable insight into potential...
developments and applications for the ruminant sector. As antibiotics are being phased out of livestock production, cost-effective, non-antibiotic strategies must be developed to meet consumer demands for more environmental friendly animal production while also supporting the world’s need for more animal protein.

References


