Gut health: opportunities and challenges

Pietro Celi
Senior Scientist, DSM Nutritional Products

Introduction
Optimal gastrointestinal health and functionality is essential for sustainable animal production. Effective functionality (digestion and absorption of feed) and immune status of the gastrointestinal tract (GIT) are important factors in determining animal performance. Several complex mechanisms are involved in GIT functionality and health, therefore it is crucial to deepen our knowledge of these interactions to develop strategies for the modulation of GIT functionality and health. Over the last few decades, the adoption of genetic selection for high growth and reproductive traits, the implementation of advanced husbandry techniques, clarity of understanding in digestive physiology and dietary requirements of farmed animals has led to significant improvements in productive performance. In this regard, a crucial question for animal scientists is: “Has animal performance reached its genetic/physiological limits?” It is within this context that the concept of “gut health” has started to attract significant interest within the animal science community.

However, while gut health is an increasingly important topic in animal nutrition, a clear scientific definition is still lacking. While in human medicine gut health is often associated with the “absence of clinical diseases”, this definition cannot be applied to farm animals as it is well known that animal performance can be impaired without any clinical signs of disease.

Gut Health
As proposed by Conway, there are three major components of gut health: the diet, the mucosa, (the innermost layer of the GIT) and indigenous gut bacteria. The mucosa forms a complex and dynamic equilibrium within the GIT that ensures efficient functioning of the digestive system. Perhaps a more comprehensive definition of gut health would be “a steady state where the microbiome and the intestinal tract exist in symbiotic equilibrium and where the welfare and performance of the animal is not constrained by intestinal dysfunction”. This definition combines the principal components of gut health, with effective digestion and absorption of feed and effective immune status (Figure 1). All these components play a critical role in GIT physiology, animal health, welfare and performance. A clear understanding of gut health requires the characterization of the interactions between all of these components.
Gut microbiota

Several factors such as changes in feeding practices, imbalanced diet (e.g. excess protein in pigs or starch in ruminants), stress (e.g. thermal, weaning, transport, regrouping, overcrowding and poor management and hygiene conditions) can result in an impairment of the GIT microbiome. This in turn impacts, often negatively, the functionality of the host’s local defense system. Therefore a normal, stable and diverse GIT microbiota, as well as an intact and effective GIT barrier, are required to maintain gut health. The intestinal microbiota contributes to several physiological functions such as digestion and absorption, regulation of energy homeostasis, prevention of mucosal infections and modulation of the immune system. The GIT microbiota prevents colonization by potentially pathogenic microorganisms, provides energy for the GIT wall from undigested nutrients and regulates the mucosal immune system by means of immune stimulators. A crucial role of the microbiota is the maintenance of the GIT barrier integrity and functionality.

The microbiota composition and the metabolites produced by the bacteria are vital for the maintenance of optimal gut health. In young animals the microbiota composition and its diversity can be influenced by environmental and management factors as it develops over time before reaching equilibrium in adult animals. The absence of specific bacterial families can result in a decrease in anti-inflammatory and metabolites such as butyrate, an organic acid responsible for providing the right levels of energy to the GIT. Consequently, dietary manipulation of the GIT microbiota composition represents an attractive tool to prevent gut health issues and to promote animal performance. Nutritional interventions should be designed to promote conditions in the GIT that would create and maintain a balance between the host and the GIT microbiota, and prevent disturbance of the structure and function of the GIT. Therefore a critical question that needs to be answered in order to advance our understanding of intestinal ecology is “what are the factors that influence the development of the GIT microbiota in farm animals?”

Figure 1: Schematic representation of the different components of the intestinal ecology important in determining gut health and growth in production animals. Each component interacts with the other in order to maintain a dynamic equilibrium, a state defined as gut health. For each component the major factors of influence within the component are given.
While standard culture-based techniques may only be able to identify as little as 1% of the GIT microbiome, the development and availability of high-throughput techniques like 16S sequencing (phylogenetic composition), metagenomics (functional capability), metatranscriptomics (functional intent) and metabolomics (metabolic impact) are providing a more comprehensive understanding of the changes in the composition of the intestinal microbiota and their secreted metabolites, providing valuable information on the GIT microbial networks and on their metabolic activities. Despite the ever-growing number of studies on the GIT microbiome, the biological functions of the different microbial populations are often still unclear. One of the obstacles in the advancement of our understanding in the changes in the GIT microbiome composition, its metabolic activities and interactions with the host is represented by the largely unknown number of bacterial species harboured in the GIT. In ruminants and swine, between 300 to 1,000 unique species have been estimated to be harbourd in the GIT, while for gallinaceous fowl (including turkey, chicken and quail) this number is much higher with more than 2,200 species. It is important to highlight the fact that only 915 species in the chicken and 464 in the turkey have been described so far. However, while bacterial diversity in general, and the presence of specific groups of bacteria have been associated with health benefits, it remains very challenging to define dysbacteriosis in light of the fact that the exact composition of the GIT microbiome and the factors that contribute to its development are still largely unknown. While the adoption of “omics” techniques is rapidly increasing our understanding of intestinal ecology, these techniques do not allow us to discriminate between a “normal” or an “optimal” GIT microbiome composition. Indeed, the main limitation of these techniques is that they yield a large amount of data with a large proportion of unknown features (unidentified species) making their biological interpretation challenging. Furthermore, the multifaceted and largely unknown interactions between microbial populations on the one hand, and the GIT microbiota and the host on the other hand add another level of complexity to this area of research.

The gastrointestinal barrier

Several studies have been performed to elucidate the interaction between the host and the GIT microbiota. There is strong evidence that the intestine regulates GIT barrier functions such as mechanical, humoral, muscular, neurological and immunological elements, and that the GIT feeds back information such as energy uptake and other conditions to the central nervous system via the vagus nerve and hormones. To characterize the functions of this complex structural and function entity, a thorough investigation of both each individual component (mucosa, microbiome, immune status, diet) and their interactions is required. When an animal encounters pathogens the immune system is stimulated, and the animal’s growth potential is reduced, resulting in higher production costs for farmers. The release of pro-inflammatory cytokines induces behavioral changes, decrease in average daily gain and lower protein deposition rate in muscle. Protein deposition is reduced due to metabolic changes that redirect valuable nutrients (amino acids, vitamins, minerals) to support the host’s immunological defenses. Considering that the requirements of these essential nutrients increase when an animal needs to mount an immune response, it is critical to characterize the nutritional costs required to mount an effective immune response in order to optimize feed efficiency and gut health. Feeding a diet that fails to provide adequate amounts of these essential nutrients will immune-compromise the animal. In-feed nutritional supplementation with additives such as DSM’s range of Eubiotics represent a valuable solution to address any nutritional deficiencies.

Figure 2: Schematic representation of the different components of the GIT barrier.
Gut health biomarkers

The development of biomarkers of gut health is imperative to gain clarity of understanding of the patho-physiological events that influence the intestinal barrier, its functionality and the ecology of the GIT microbiota. While there is considerable knowledge in biomarkers that are indicative of the GIT ability to digest, absorb, transport and secrete major macro and micro-nutrients, a large gap in the literature exists in relation to biomarkers of GIT permeability, GIT barrier function, or biomarkers that are indicative of the functional presence of beneficial microbiota or their metabolites. Several techniques are available to assess intestinal permeability and integrity, but non-invasive methods are still far from giving a full representation of the gut microbiota. Currently available techniques such as ingestible gas capsules provide a non-invasive assessment method to measure a range of gas biomarkers potentially important for gut health research. The complex microbial ecosystem inhabiting the GIT of farm animals produces a wide range of metabolites that have been associated to improved or decreased gut health. An inventory of possible gut health biomarkers has been made for use in pigs and poultry, however the overall paucity of information on gut health biomarkers in farm animals is remarkable. Although gut health has been widely recognized as one of the main factors to ensure optimal performance, clarity of understanding of the pathophysiology of gut health in farm animal will allow the design of specific nutritional interventions as well as the early diagnosis of potential issues in gut health.

Conclusion

Despite the numerous techniques available to measure and evaluate gut health, the industry is facing the major challenge to develop a set of non-invasive biomarkers that can reliably reflect gut health status. While animal scientists work to establish whether biomarkers measured in blood, feces, urine and breadth provide a reasonable index of gut health, animal producers need a reliable index to monitor changes and potential threats in gut health to be able to act on it. Nowadays, nutritional supplementation represents a valid option to maximize nutrient intake and, ultimately, optimize performance. A balanced combination of feed additives, including probiotics, organic acids and essential oils, can make the difference when trying to achieve optimal gut health.

References available upon request.